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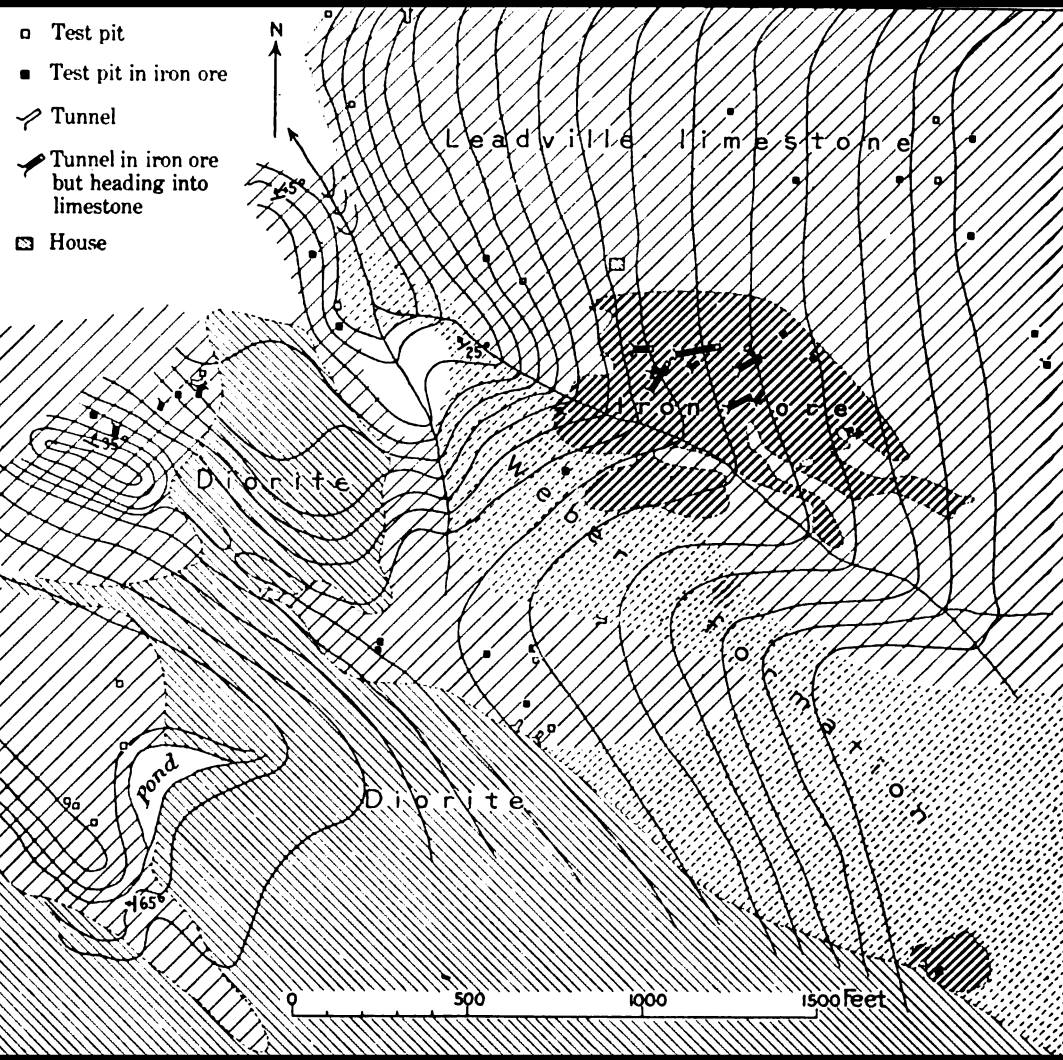

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 380

CONTRIBUTIONS

TO

ECONOMIC GEOLOGY

1908

PART I.—METALS AND NONMETALS, EXCEPT FUELS

C. W. HAYES AND WALDEMAR LINDGREN
GEOLOGISTS IN CHARGE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1909

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CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1908, PART I.

C. W. HAYES and WALDEMAR LINDGREN, *Geologists in charge.*

INTRODUCTION.

By C. W. HAYES, *Chief geologist.*

This bulletin is the seventh of a series, including Bulletins 213, 225, 260, 285, 315, and 340, Contributions to Economic Geology for 1902, 1903, 1904, 1905, 1906 (Part I), and 1907 (Part I), respectively. These bulletins are prepared primarily with a view to securing prompt publication of the economic results of investigations made by the United States Geological Survey. By means of the bibliographies accompanying the several groups of papers they also serve as a guide to the economic publications and afford a better idea of the work which the Survey as an organization is carrying on for the direct advancement of mining interests throughout the country than can readily be obtained from the more voluminous final reports.

The first two bulletins of this series included numerous papers relating to the economic geology of Alaska. In view of the rapid increase of economic work, both in Alaska and in the States, and the organization of a division of Alaskan mineral resources distinct from the division of geology, it was in 1905 considered advisable to exclude all papers relating to Alaska. These were brought together in a separate volume entitled "Report of progress of investigations of mineral resources of Alaska in 1904," Bulletin 259. A similar segregation of papers relating to Alaska has since been made and published annually.

During 1906 a further change in the arrangement of the economic bulletin seemed desirable. The former section of iron ores and non-metallic minerals was divided and M. R. Campbell was placed in charge of a new section devoted to the investigation of fuels. This change in Survey organization was used as a basis for a separation of the economic bulletin, based on subjects. The present bulletin

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is therefore restricted to the work of the Survey in 1908 in the metals, structural materials, and other nonmetals except fuels. A separate bulletin will be issued later (Bulletin 381) relating to Survey work on coal, lignite, peat, oil, and gas.

The papers included in the present volume are such only as have a direct economic bearing, all questions of purely scientific interest being excluded.

The papers are of two classes—(1) preliminary discussions of the results of extended economic investigations, which will later be published by the Survey in more detailed form; (2) comparatively detailed descriptions of occurrences of economic interest, noted by geologists of the Survey in the course of their field work, but not of sufficient importance to necessitate a later and more extended description.

The papers have been grouped according to the subjects treated and each group has been issued as soon as ready, in advance of the complete bulletin. At the end of each section is given a list of previous publications on that subject by this Survey. These lists will be serviceable to those who wish to ascertain what has been accomplished by the Survey in the investigation of any particular group of mineral products. They are generally confined to Survey publications, though a few titles of important papers published elsewhere by members of the Survey are included.

Material assistance in the preparation of this volume has been rendered by W. C. Phalen, and to him is largely due the promptness of its publication.

The results of the Survey work in economic geology have been published in a number of different forms, which are here briefly described:

1. *Papers and reports accompanying the Annual Report of the Director.*—Prior to 1902 many economic reports were published in the royal octavo cloth-bound volumes which accompanied the Annual Report of the Director. This form of publication for scientific papers has been discontinued and a new series, termed Professional Papers, has been substituted.

2. *Bulletins.*—The bulletins of the Survey comprise a series of paper-covered octavo volumes, each containing usually a single report or paper. These bulletins, formerly sold at nominal prices, are now distributed free of charge to those interested in the special subject discussed in any particular bulletin. This form of publication facilitates promptness of issue for economic results, and most economic reports are therefore published as bulletins. Their small size, however, precludes the use of large maps or plates, and reports containing large illustrations are issued in the series of professional papers.

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3. *Professional Papers.*—This series, paper covered but quarto in size, is intended to include such papers as contain maps or other illustrations requiring the use of a large page. The publication of the series was commenced in 1902, and the papers are distributed in the same manner as are the bulletins.

4. *Monographs.*—This series consists of cloth-bound quarto volumes, and is designed to include exhaustive treatises on economic or other geologic subjects. Volumes of this series are sold at cost of publication.

5. *Geologic folios.*—Under the plan adopted for the preparation of a geologic map of the United States the entire area is divided into small quadrangles, bounded by certain meridians and parallels, and these quadrangles, which number several thousand, are separately surveyed and mapped. The unit of survey is also the unit of publication, and the maps and descriptions of each quadrangle are issued in the form of a folio. When all the folios are completed, they will constitute a Geologic Atlas of the United States.

A folio is designated by the name of the principal town or of a prominent natural feature within the quadrangle. It contains topographic, geologic, economic, and structural maps of the quadrangle, and in some cases other illustrations, together with a general description.

Under the law copies of each folio are sent to certain public libraries and educational institutions. The remainder are sold at 25 cents each, except such as contain an unusual amount of matter, which are priced accordingly.

Circulars containing complete lists of these folios, showing the location of the quadrangle areas they describe, their prices, etc., are issued from time to time and may be obtained on application to the Director of the United States Geological Survey. The following list shows the folios issued since January 1, 1908, and in an advanced state of preparation, also the economic products discussed in the text of each, the products of greatest importance being printed in italic:

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List of geologic folios issued between January 1, 1908, and July 1, 1909, showing mineral resources described.

No.	Name of folio.	State.	Area in square miles.	Author.	Mineral products described as occurring in area of folio.
154	Winslow	Ark.-Ind. T.	969	Purdue, A. H	Limestone, clay, iron, oil, gas, zinc, lead, coal, underground water.
155	Ann Arbor	Mich	885	Russell, I. C.; Leverett, F.	Limestone, road material, clay, *marl*, cement, peat, underground water.
156	Elk Point	S. Dak.-Nebr.-Iowa.	878	Todd, J. E	Clay, sand, cement, volcanic ash, lignite, *underground water*.
157	Passaic	N. J.-N. Y	906	Darton, N. H.; Bayley, W. S.; Salisbury, R. D.; Kümmel, H. B.	*Iron*, graphite, copper, building stone, road material, *pottery clay*, brick clay, lime, sand and gravel, peat, underground water.
158	Rockland	Me	215	Bastin, E. S.	*Lime*, road material, cement, *granite*, clay, sand, peat, gravel.
159	Independence	Kans	950	Schrader, F. C	*Oil, gas*, coal, building stone, road material, lime, glass sand, cement materials, clay, underground water.
160	Accident-Grantsville	Md.-Pa.-W. Va.	460	Martin, G. C	*Coal*, fire clay, lime, building stone, road material, iron.
161	Franklin Furnace	N. J	226	Spencer, A. C.; Salisbury, R. D.; Kümmel, H. B.; Palache, Chas.; Wolff, J. E.	*Iron*, zinc, graphite, limestone, slate, clay, sand and gravel, building stone, road material.
162	Philadelphia (Norristown, Germantown, Chester, Philadelphia).	Pa.-N. J.-Del.	915	Bascom, F.; Clark, W. B.; Darton, N. H.; Kümmel, H. B.; Salisbury, R. D.; Miller, B. L.; Knapp, G. N.	Building stone, road material, *lime*, magnesium carbonate, soapstone, iron, gravel, sand, *pottery clay*, *feldspar*, *brick clay*, marl.
163	Santa Cruz	Cal	950	Branner, J. C.; Newsome, J. F.; Arnold, R.	Gold, *bituminous rock*, *petroleum*, building stone, road material, lime, cement material, diatomaceous shale, sand, underground water.
164	Belle Fourche	S. Dak	849	O'Harra, C. C.; Darton, N. H.	Gypsum, lime, clay, building stone, bentonite, *underground water*.
165	Aberdeen - Redfield (Northville, Aberdeen, Redfield, Byron).	S. Dak	3,383	Todd, J. E	Lignite, clay, sand, gravel, salt, gas, *underground water*.
166	El Paso	Tex	889	Richardson, G. B.	Tin, *clay*, *cement*, flux, lime, sand, gravel, *underground water*.
167	Trenton	N. J.-Pa	912	Bascom, F.; Darton, N. H.; Kümmel, H. B.; Clark, W. B.; Miller, B. L.; Salisbury, R. D.	*Pottery clay*, brick clay, *molding sand*, building sand, gravel, *marl*, building stone, road material, lime, copper, barite.
168	Jamestown - Tower (Jamestown, Eckelson, Tower).	N. Dak	2,460	Willard, D. E	Underground water.

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List of geologic folios in preparation.

Name of folio.	State.	Area in square miles.	Author.	Mineral products described as occurring in area of folio.
Engineer Mountain	Colo	236	Cross, W	Limestone and building stone.
Foxburg	Pa	225	Shaw, E. W	*Coal, oil, gas*, sand, clay.
Johnstown	Pa	228	Phalen, W. C	Coal, clay, limestone, cement material, concrete materials, building stone, road materials, glass sand, iron ore.
Mercersburg-Chambersburg.	Pa	458	Stose, G. W	*Iron*, manganese, white clay, barite, *lime*, cement material, sand, clay, building stone, marble, road material, underground water.
Warren	Pa	226	Butts, Chas	Oil, *gas*, *petroleum*, clay, coal, building stone.
Watkins Glen-Catatonk	N. Y	1,770	Williams, H. S.; Tarr, R. S.; Kindle, E. M.	Sand, gravel, clay, underground water.

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INVESTIGATIONS RELATING TO NONMETALLIC MINERAL RESOURCES AND IRON ORES.

By C. W. HAYES, *Chief geologist.*

PUBLICATIONS ISSUED AND IN PREPARATION.

During the year 1908 the following publications, consisting wholly or in part of the results of investigations on the nonmetallic mineral resources of the United States, were issued by the Survey. Publications relating to coal, lignite, peat, etc., except folios, are not included in this list.

Professional Papers:

56. Geography and geology of a portion of southeastern Wyoming, with special reference to coal and oil, by A. C. Veatch.

Bulletins:

322. Geology and oil resources of the Santa Maria oil district, Santa Barbara County, Cal., by Ralph Arnold and Robert Anderson.
329. Organization, equipment, and operation of the structural-materials testing laboratories at St. Louis, Mo., by R. L. Humphrey.
331. Portland cement mortars and their constituent materials; results of tests made at the structural-materials testing laboratories, Forest Park, St. Louis, Mo., 1905–1907, by R. L. Humphrey and William Jordan, jr.
338. The iron ores of the Iron Springs district, southern Utah, by C. K. Leith and E. C. Harder.
340. Contributions to economic geology, 1907. Part I.—Metals and nonmetals, except fuels. C. W. Hayes and Waldemar Lindgren, geologists in charge.
346. Structure of the Berea oil sand in the Flushing quadrangle, Harrison, Belmont, and Guernsey counties, Ohio, by W. T. Griswold.
349. Economic geology of the Kenova quadrangle, Kentucky, Ohio, and West Virginia, by W. C. Phalen.
350. Geology of the Rangely oil district, Rio Blanco County, Colo., with a section on the water supply, by H. S. Gale.
351. The clays of Arkansas, by J. C. Branner.
354. The chief commercial granites of Massachusetts, New Hampshire, and Rhode Island, by T. N. Dale.
355. The magnesite deposits of California, by F. L. Hess.
357. Preliminary report on the Coalinga oil district, Fresno and Kings counties, Cal., by Ralph Arnold and Robert Anderson.
359. Magnetite deposits of the Cornwall type in Pennsylvania, by A. C. Spencer.
364. Geology and mineral resources of the Laramie Basin, Wyoming; a preliminary report, by N. H. Darton and C. E. Siebenthal.
365. The fractionation of crude petroleum by capillary diffusion, by J. E. Gilpin and M. P. Cram.

(Road materials of southern and eastern Maine, Bulletin No. 33, U. S. Department of Agriculture, by Henry Leighton and Edson S. Bastin.)

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The following folios are those in which nonmetallic products of considerable importance are described. The substances printed in italics are of most importance.

Folios:

154. Winslow (Ark.-Ind. T.), by A. H. Purdue. Limestone, clay, iron, oil, gas, zinc, lead, coal, underground water.
155. Ann Arbor (Mich.), by I. C. Russell and F. Leverett. Limestone, road material, clay, *marl*, cement, peat, underground water.
156. Elk Point (S. Dak.-Nebr.-Iowa), by J. E. Todd. Clay, sand, cement, volcanic ash, lignite, *underground water*.
157. Passaic (N. J.-N. Y.), by N. H. Darton, W. S. Bayley, R. D. Salisbury, and H. B. Kümmel. *Iron*, graphite, copper, building stone, road material, *pottery clay*, brick clay, lime, sand and gravel, peat, underground water.
158. Rockland (Me.), by E. S. Bastin. *Lime*, road material, cement, *granite*, clay, sand, peat, gravel.
159. Independence (Kans.), by F. C. Schrader. *Oil*, *gas*, coal, building stone, road material, lime, glass sand, cement materials, clay, underground water.
160. Accident-Grantsville (Md.-Pa.-W. Va.), by G. C. Martin. *Coal*, fire clay, lime, building stone, road material, iron.
161. Franklin Furnace (N. J.), by A. C. Spencer, R. D. Salisbury, H. B. Kümmel, Charles Palache, and J. E. Wolff. *Iron*, *zinc*, graphite, limestone, slate, clay, sand and gravel, building stone, road metal.
162. Philadelphia (Pa.-N. J.-Del.), by F. Bascom, W. B. Clark, N. H. Darton, H. B. Kümmel, R. D. Salisbury, B. L. Miller, and G. N. Knapp. Building stone, road material, *lime*, magnesium carbonate, soapstone, iron, gravel, sand, *pottery clay*, *feldspar*, *brick clay*, marl.
163. Santa Cruz (Cal.), by J. C. Branner, J. F. Newsome, and R. Arnold. Gold, *bituminous rock*, *petroleum*, building stone, road material, lime, cement material, diatomaceous shale, sand, underground water.

Reports for which the field work has been completed and which are in press or in an advanced state of preparation are the following:

Iron and manganese.

Iron ores, fuels, and fluxes of the Birmingham district, Alabama, by E. F. Burchard, Charles Butts, and E. C. Eckel. (Bulletin 400.)

The iron-ore supplies of the United States, by C. W. Hayes. (In Bulletin 394.)

The manganese deposits of the United States and foreign countries, by E. C. Harder.

Petroleum and natural gas.

Geology and oil resources of the Coalinga district, California, by Ralph Arnold and Robert Anderson. (Bulletin 398.)

Systematic comparison of the crude petroleums in the United States, by D. T. Day.

Oil and gas in the Sewickley, Carnegie, and Clarion quadrangles, Pennsylvania, by M. J. Munn.

Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming, by N. H. Darton. (Professional Paper 65.)

Building stones, road metal, etc.

The granites of Vermont, by T. Nelson Dale.

Granites of the southeastern Atlantic States, by T. L. Watson.

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Cement and concrete materials.

Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming, by N. H. Darton. (Professional Paper 65.)

Structural materials in parts of Oregon and Washington, by N. H. Darton. (Bulletin 387.)

The fire-resistive properties of various building materials, by R. L. Humphrey. (Bulletin 370.)

The structural materials in the District of Columbia region, by N. H. Darton.

Investigations of concrete and reinforced concrete at ten technological institutions, by R. L. Humphrey and R. V. Engstrom.

The cement materials and industry of the United States, by E. C. Eckel.

Clays.

Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming, by N. H. Darton. (Professional Paper 65.)

Economic geology of the Johnstown quadrangle, Pennsylvania, by W. C. Phalen.

Gypsum and magnesite.

Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming, by N. H. Darton. (Professional Paper 65.)

A reconnaissance of the gypsum deposits of California, by F. L. Hess.

Miscellaneous.

Geology of the Maine pegmatites, by E. S. Bastin.

The occurrence of diamonds in the United States and elsewhere, by G. F. Kunz.

The phosphate deposits of the United States, by F. B. Van Horn.

FIELD WORK.

As in previous years, a large part of the work on nonmetalliferous minerals during 1908 was carried on in connection with other investigations, chiefly areal surveys. By reason of the character of these deposits they can not generally be studied with advantage in advance of detailed topographic mapping, and their relations to the areal distribution of the rock formations are such that detailed areal geologic surveys are also generally necessary.

Iron ores, manganese and aluminum ores.—A systematic review of all available information relating to the iron-ore supplies of the United States was made and a report containing a brief description of the distribution and geologic relations of the ores, with estimates of tonnage, was prepared by C. W. Hayes for the Conservation Commission. This report will be published with other reports of similar nature as Bulletin 394.

Field work on the manganese deposits of the United States was completed by E. C. Harder, and a detailed report, which contains also a summary of all available information concerning foreign deposits, is in preparation.

Field work has been continued on the Appalachian iron ores by Mr. Harder in Virginia and by Mr. Burchard in Tennessee, Georgia,

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and Alabama. It is proposed to prepare as soon as possible a monographic report on this district.

The developments in the Lake Superior district have been followed closely by C. R. Van Hise and his assistants, and a report summarizing the various monographs already published and bringing information and conclusions regarding the relations of the iron ores down to date is now in preparation. This report contains important conclusions as to the origin of the ores and marks a decided advance toward the establishment of a quantitative basis for geologic theories.

Structural materials.—Cooperation has been continued with the technologic branch in the study of building materials by N. H. Darton and E. F. Burchard, and valuable data on this important subject have been obtained.

The systematic work on the New England granites was completed by T. Nelson Dale, and the third report on this subject is in preparation. It is proposed now to take up a similar investigation of the marble and marble-quarrying industry.

The report by T. L. Watson on the granites of the Southern Atlantic States has been completed and will be issued during the year.

The field work on the roofing slates of Arkansas has been completed by A. H. Purdue and a report is being published by the State.

Oil and gas.—Detailed surveys on oil and gas fields have been continued by M. J. Munn in western Pennsylvania, by J. A. Taff in Oklahoma, by C. W. Washburne in Colorado, and by Ralph Arnold in California. A reconnaissance of certain reported occurrences of oil in Nevada was made by Robert Anderson. Papers relating to oil and gas are this year included in the second part of Contributions to economic geology for 1908, together with papers on other mineral fuels.

Phosphates.—A report on the phosphate deposits of the United States was prepared by F. B. Van Horn for the Conservation Commission and will be included in Bulletin 394 with other reports of a similar nature.

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INVESTIGATIONS RELATING TO DEPOSITS OF METALLIFEROUS ORES.

By WALDEMAR LINDGREN, *Geologist in charge.*

PUBLICATIONS OF THE YEAR.

During the year the following publications on subjects connected with the investigations of deposits of metalliferous ores (except iron and manganese) in the United States have been issued by the Geological Survey:

Professional Papers:

62. The geology and ore deposits of the Cœur d'Alene district, Idaho, by F. L. Ransome and F. C. Calkins.

63. Economic geology of the Georgetown quadrangle, together with the Empire district, Colorado, by J. E. Spurr and G. H. Garrey; with general geology by S. H. Ball.

Bulletins:

328. The gold placers of parts of Seward Peninsula, Alaska, by A. J. Collier, F. L. Hess, P. S. Smith, and A. H. Brooks.

337. The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska, by L. M. Prindle, with sections by F. L. Hess and C. C. Covert.

340. Contributions to economic geology, 1907, Part I: Metals and nonmetals except fuels. C. W. Hayes, Waldemar Lindgren, geologists in charge.

345. Mineral resources of Alaska in 1907, by A. H. Brooks and others.

347. The Ketchikan and Wrangell mining districts, Alaska, by F. E. and C. W. Wright.

353. Geology of the Taylorsville region, California, by J. S. Diller.

358. Geology of the Seward Peninsula tin deposits, Alaska, by Adolph Knopf.

364. Geology and mineral resources of the Laramie Basin, Wyoming, by N. H. Darton and C. E. Siebenthal.

Folios:

161. Franklin Furnace, New Jersey, by A. C. Spencer, R. D. Salisbury, H. B. Kümmel, Charles Palache, and J. E. Wolff. Contains descriptions of iron, zinc, and manganese deposits.

163. Santa Cruz, California, by J. C. Branner, J. F. Newsome, and Ralph Arnold. Contains descriptions of gold deposits.

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The following list comprises reports which are now in the press or in the editor's hands:

Professional Paper:

66. Geology and ore deposits of the Goldfield district, Nevada, by F. L. Ransome.

Bulletins:

374. Mineral resources of the Kotsina-Chitina region, Alaska, by F. H. Moffit and A. G. Maddren.

375. The Fortymile district, Yukon-Tanana region, Alaska, by L. M. Prindle.

379. Mineral resources of Alaska, 1908, by A. H. Brooks and others.

384. A geological reconnaissance in northern Idaho and northwestern Montana, by F. C. Calkins.

397. Mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Arizona, by F. C. Schrader.

The Innoko gold placer district, Alaska, by A. G. Maddren.

The mineral resources of the Nabesna-White district, Alaska, by F. H. Moffit and Adolph Knopf.

Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska, by P. S. Smith.

Geology and ore deposits of the Bullfrog district, Nevada, by F. L. Ransome, W. H. Emmons, and G. H. Garrey.

The following list comprises reports for which the field work has been completed, but which have not yet been transmitted to the press:

Resurvey of the Leadville mining district, Colorado, by S. F. Emmons and J. D. Irving.

The Tertiary auriferous gravels of the Sierra Nevada, by Waldemar Lindgren.

Copper deposits of the Butte district, Montana, by W. H. Weed.

Economic geology of the Park City mining district, Utah, by J. M. Boutwell and L. H. Woolsey.

Reconnaissance of deposits of metalliferous ores of New Mexico, by Waldemar Lindgren, L. C. Graton, and C. H. Gordon.

The copper deposits of Shasta County, Cal., by L. C. Graton.

Geology and ore deposits of the Phillipsburg quadrangle, Montana, by W. H. Emmons and F. C. Calkins.

Notes on some mining districts in the southern part of Humboldt County, Nev., by F. L. Ransome.

Reconnaissance of mining districts in western Elko, Eureka, and Lander counties, Nev., by W. H. Emmons.

Geology and ore deposits of the Dahlonega district, Georgia, by Arthur Keith.

The ore deposits in the vicinity of Lake City, Colo., by J. D. Irving and H. Bancroft.

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FIELD WORK.

GENERAL STATEMENT.

The field and office work of the section of metalliferous deposits was continued during 1908 on a plan similar to that used during the preceding year, the relatively small amount of money available for the work prohibiting any enlargement of operations.

As during previous years, the supervision of the collection of metal statistics has occupied a part of the time of Messrs. Boutwell, Graton, Hess, Lindgren, and Siebenthal. These duties, of course, took some time from the purely geologic work, but each year demonstrates more clearly that a thorough knowledge of all occurrences and conditions of production of a metal is indispensable to the economic geologist who desires to make a specialty of that metal. The attempt is made to reduce to a minimum the purely mechanical work done by the geologist for such purposes. He will retain the supervision and the reviewing, and this connection with practical work in his branch, far from being a detriment, will enable him to obtain a much better knowledge of the resources of the nation; moreover, the data collected, if intelligently handled, will allow him to draw many important geologic conclusions.

WORK BY LOCALITIES.

The following notes summarize the geologic work by members of the Survey in 1908, so far as the metalliferous deposits, except iron, are concerned:

ALASKA.

For the operations in Alaska, which, under the direction of A. H. Brooks, cover a wide field, the reader is referred to the report on the mineral resources of Alaska in 1908, which has just been issued as Bulletin 379.

ARIZONA.

No field work was undertaken in the mining districts of Arizona during 1908, but the report of a reconnaissance of the deposits in Mohave County, by F. C. Schrader, was completed during the year, and will, as indicated above, be published as Bulletin 397.

CALIFORNIA.

The mapping of the Randsburg quadrangle, in connection with special studies of the gold deposits in that district, was begun by

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F. L. Hess during the last months of the year. The field work of this complicated area is not yet completed and will be continued in 1909.

The preparation of a report on the copper deposits of Shasta County, by L. C. Graton, aided by B. S. Butler, was continued and it is expected that the report will be issued as a professional paper at the close of 1909.

COLORADO.

A topographic map of the vicinity of Breckenridge, on the scale of 1:24,000, was prepared by the topographic branch during the summer of 1908, and in September F. L. Ransome began the study of the geology and ore deposits, which, however, was interrupted by the early snows of October. The investigation will be completed in 1909.

In the month of July J. M. Hill devoted two weeks to a reconnaissance of the mining districts in the eastern part of Gunnison County, an account of which will be found elsewhere in this bulletin. H. Bancroft, as assistant to Whitman Cross, spent some weeks of the fall in completing an investigation of the mines near Lake City, Hinsdale County.

NEVADA.

During the early summer of 1908 F. L. Ransome completed the field work in the Goldfield district and devoted the following months to a reconnaissance of mining districts in southern Humboldt County, as well as to an examination of the Yerington copper-mining district, an account of which will be found on other pages of this bulletin.

During the same time W. H. Emmons made a reconnaissance of the little-known mining districts of western Elko County and adjacent parts of Lander and Eureka counties.

OREGON.

In connection with areal geologic work, J. S. Diller, assisted by G. F. Kay, continued the examination of the gold-quartz veins, copper deposits, and placers of southwestern Oregon. A summary of the mining developments has been prepared for the present bulletin. In connection with other work D. F. MacDonald visited the Bohemia mining district, and a brief report on its geology and deposits is also contained in this volume.

SOUTH DAKOTA.

F. L. Hess visited the Black Hills during the summer and has prepared an account of the tin, tungsten, and tantalum deposits of that region, which is published in this bulletin.

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UTAH.

In July, August, and September B. S. Butler completed the geologic mapping of the Frisco special area in Beaver County, and the investigation of the mines in that vicinity will, it is expected, be finished during the field season of 1909.

APPALACHIAN STATES.

In November, 1908, H. D. McCaskey spent some weeks examining the mines of the Dahlonega belt in Cherokee County, Ga.

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GOLD AND SILVER.

NOTES ON THE ECONOMIC GEOLOGY OF SOUTHEASTERN GUNNISON COUNTY, COLORADO.

By J. M. Hill.

INTRODUCTION.

During the latter part of July, 1908, the writer had an opportunity to visit some of the mining camps of southeastern Gunnison County, Colo. The following report is a summary of the results obtained. Little time was available, and as a consequence the material for an economic paper is meager. No topographic survey of this county has been made, and no good maps are available. The sketch map (Pl. I) used as a base for this work is taken from a county map, on which some corrections were found necessary. The mines in these districts were for the most part closed, partly owing to the low price of silver, but most of the accessible workings were visited. Much of the information used in this report was given by local miners and operators and, where possible, verified by the writer, who wishes here to acknowledge the courtesy shown him by all the mining men of the district.

GEOGRAPHY.

The Continental Divide here follows the Sawatch Mountains, which form the eastern boundary line of Gunnison County. From the main range numerous spurs run out to the plateau region south and west of Tomichi Creek. Between these spurs there are several large streams, the main one in the southern part being Tomichi Creek. This stream heads near the center of the east boundary line of the area mapped on Plate I, just under the crest of the divide. It runs southward for about 18 miles and then turns to the northwest to join Gunnison River just west of Gunnison. Cochetopa

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Creek, a southern branch, joins Tomichi Creek about 2 miles below Parlin, after running northward for 7 miles.

The next largest drainage system is that of Quartz Creek, which flows through the central part of the area. This stream heads a mile north of the headwaters of Tomichi Creek and flows in a general southwesterly direction to that creek at Parlin. Quartz Creek has three large branches—North Fork, Ohio Creek, and Alder Creek, named from east to west. Minor branches are South Fork and Armstrong Gulch. Only one tributary enters Quartz Creek from the south.

To the north of the Quartz Creek drainage basin there is a high divide, north of which the streams all flow into the headwaters of Gunnison River. Willow Creek is the most eastern stream of this system, and the town of Tincup is situated at the junction of its three branches. Lottis Creek, to the west, is the only other stream of this drainage area shown on the map.

The Continental Divide averages well above 12,000 feet in elevation, and of the peaks within the area of the sketch map Fairview Peak, Cross Mountain, and Fossil Ridge are more than 11,000 feet high. The general slope, as shown by the drainage lines, is southwestward in the area south of an east-west line between Fairview Peak and Alpine Pass, and northward in the area north of the same line. The appended table gives the elevations of the towns:

Elevations of towns in southeastern Gunnison County, Colo.

Town.	Elevation (feet).	Authority.
Parlin	7,942	Denver and Rio Grande R. R. survey.
Sargents	8,875	Do.
Ohio City	8,546	Colorado and Southern Ry. survey.
Pitkin	9,190	Do.
Quartz	9,642	Do.
Tincup	9,650	Aneroid.
White Pine	10,000	Do.

There are two narrow-gage railroads in this area. The Montrose branch of the Denver and Rio Grande Railroad follows Tomichi Creek from Sargents to Gunnison, and the Gunnison branch of the Colorado and Southern Railway crosses the Sawatch Range at Alpine tunnel, at the head of Quartz Creek, and follows that stream to Parlin, whence it parallels the Denver and Rio Grande to Gunnison. On both of these roads there is daily service each way.

Many good wagon roads and trails traverse this region, and two passes over the range are in use. Alpine or Cottonwood Pass, to the north, is crossed twice daily by the mail stage from Buena Vista to

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Tincup. Monarch Pass, to the south, is not used as much, but gives a direct road from White Pine or Sargents to the mining town of Monarch, on the east side of the range.

The principal supply points for these districts are Pitkin and Ohio City. They are both on Quartz Creek, so that they get fair railway service most of the year; and are centrally located. Tincup supports two stores, but there are many vacant houses in town. White Pine is almost deserted, though a few men are still working in the vicinity. Tomichi is a town of the past, only one half-ruined building remaining on its site. Sargents and Parlin, in the lower Tomichi Valley, are supported more by ranchers than by mining men, as the miners of the southwestern districts obtain their supplies from Gunnison.

GEOLOGY.

Pre-Cambrian rocks cover by far the larger portion of southeastern Gunnison County, forming the Sawatch Range and its east-west spurs. South of Tomichi Creek is a plateau, which rises about 200 feet above the stream, composed entirely of red and gray coarse-textured granites. Within this pre-Cambrian basement area there are several isolated patches of sedimentary beds, cut off usually by faults, though in one place erosion was the main factor in dividing two areas. All the formations have been much disturbed, faulting, folding, and intrusion having played an important part in their character, present distribution, and structure.

STRATIGRAPHY.

PRE-CAMBRIAN ROCKS.

The pre-Cambrian rocks are widely distributed and their structure is very complex. They consist of red and gray granites, some almost pegmatitic, and of gneiss and schists of various kinds ranging from amphibolitic to muscovitic. Three miles east-northeast of Tincup, near the crest of the main range, there is a small body of very highly metamorphosed limestones and quartzites. These are entirely inclosed by gneiss and are probably a part of the pre-Cambrian. West of Pitkin, where the section given below was measured, the granite is somewhat porphyritic and grades into a granite schist, between which and the unmetamorphosed sedimentary beds is a series of biotite schists, some of which appear to be metamorphosed quartzites. At one place in this formation a small lens of pure quartzite was seen.

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PALEOZOIC ROCKS.

The subjoined section is typical of the Paleozoic rocks in this region and gives the local names of certain characteristic formations.

Section in the Pitkin "lime belt," Gunnison County, Colo.

	Feet.
Green and red shales, somewhat carbonaceous in upper portions	70
Thin-bedded dark-blue limestone	250
Red grits	20
Massive blue limestone	30
Massive gray dolomite	60
Carboniferous (?), massive blue limestone and black chert	300
Gray and buff dolomite	20
"Buckskin" limestone, buff, very fine texture	20
Mottled red shales, locally known as pink shale	10
"Fairview" shale, mottled yellow	40
Gray dolomite	18
"Parting" quartzite, mottled white	18
Silurian (?), massive dark-gray limestone and white chert	185
Cambrian (?), white quartzite	120
Pre-Cambrian, schists, granite, etc.	

The oldest unmetamorphosed sedimentary formation of this area is a quartzite of widespread occurrence, which is found at the bottom of the section in all places. The white color of this formation is very characteristic and its texture is constant. Weathered surfaces often appear somewhat pinkish, but fresh fractures are usually white. Just above this formation is a bed of conglomerate, the pebbles of which are derived from the underlying quartzite. This conglomerate grades into a gray limestone, whose characteristics make it comparatively easy to recognize. It is usually about 100 feet thick, though in several places 190 to 200 feet were seen. It is rather light gray in color and contains a great deal of white chert, particularly in the basal portion. Between this limestone and the younger calcareous beds is a very constant bed known as the "parting" quartzite, which is somewhat darker than the quartzite at the base of the section and shows brown and pink mottling, even on freshly broken surfaces.

The lower portion of the limestones above the "parting" quartzite shows several minor differences in different localities. At most of the places where this part of the section was exposed the following characteristics were noted: Just above the quartzite is a thin bed (rarely over 20 feet thick) of gray dolomite of rather coarse texture, almost invariably followed by a series of shales. At the best exposure these shales were 50 feet thick, but they are more commonly very thin or entirely absent. The lower part of the shales is yellow, but they are mottled with red in the central portion, and are very red and more calcareous at the top. Above these shales are two thin

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beds of light-buff color. The lower is an almost pure limestone of very fine texture, called from its color the "buckskin" limestone. The bed above is a grayer buff and contains a large percentage of magnesium. It is of coarser texture than the limestone, and exhibits marked conchoidal fracture. These two beds together are nowhere more than 40 feet in thickness, and are in many places much thinner. Immediately above the buff or middle dolomite comes the heaviest bed of the section—a dark-blue, massive limestone, containing a large amount of black chert. It averages over 250 feet in thickness, though thinner in some places. It stands out in many bluffs and forms the cap rock of a large part of the Pitkin lime basin. Near the top of this formation there is usually a bed of massive gray dolomitic limestone, which is of very coarse texture and has decidedly different characteristics from the limestone above and below it. Above the massive blue limestone there is in a few places a thin bed, 20 feet or less in thickness, of red sand grits, the grains of which are in places rather large. This is followed by a series of thin-bedded blue limestones and shales, the former in many places attaining a considerable thickness. Shales are present near the top of this series, and are locally somewhat carbonaceous. Lignitic coal occurs in a few localities, and at one place a mixture of what appeared to be bog iron was seen with a mass of carbonaceous material.

One formation, not shown in the section because of its uncertain age, is a conglomerate composed of bowlders and pebbles of quartzite, dolomite, and gray and yellow limestone in a matrix of pink and white sand. It is somewhat indurated, but weathers rapidly. This conglomerate was seen in a small exposure on the south side of Quartz Creek, opposite Pitkin, and nowhere else. It overlies the massive blue limestone and must therefore be younger than that formation. That it is a remnant of a formation more recent than any in the section seems possible on account of the yellow limestone in it, as no rocks were found in this area which weather with this color. No correlation of this section with that of other localities was possible. It resembles in some ways, however, the section at Leadville, as described by Emmons.[a]

The same general succession is to be found in the exposures of the Tincup "lime belt," though some of the members are absent and there are differences in thickness of the beds represented.

INTRUSIVE ROCKS.

In many places in this region there are dikes and sheets of felsitic porphyry and granite porphyry of intrusive origin. This intrusive porphyry does not resemble the pre-Cambrian porphyritic granite,

[a] Emmons, S. F., Geology and mining industry of Leadville, Colo.: Mon. U. S. Geol. Survey, vol. 12, 1886, pp. 53–69.

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as it is gray to white in color and contains a much smaller percentage of dark minerals. The groundmass of the granite porphyry is commonly rather coarse in texture, the crystals of feldspar, biotite, and quartz being easily recognizable in hand specimens. In some places, however, the groundmass is so fine grained that no megascopic determination of its composition is possible: to such rock the term "felsitic porphyry" is applied.

LATE GRAVELS.

There has been some glaciation in the higher parts of the Sawatch Range. Glacial drift was noticed in particular in the east fork of Willow Creek about 1 mile east of Tincup, in the upper Tomichi Valley, north of White Pine, and in the valley of the middle fork of Quartz Creek, near Sherrod. All the stream beds have considerable accumulations of gravels, particularly in their wider portions.

West of Tomichi Dome is a basin entirely covered with fine soil, derived from the adjacent hills, which seems to be exceptionally fertile.

STRUCTURE.

The structure of this region is very complex and only the most prominent features can be outlined. To the north of the main east-west divide—that is, in the Tincup and Cross Mountain districts (see section A–B, fig. 1)—there are two areas of sedimentary rocks, each cut off on the east by faults. The beds dip to the east and the surface slopes at a less angle than the dip of the beds, thus exposing the youngest formations at the base of the hills. In both areas these younger beds abut against the pre-Cambrian rocks, with a stream at the junction. (See Pl. I.) In the Tincup "lime belt," as the sedimentary areas are locally called, the beds at the south end dip about 20° NE., but the dip changes to 45° E. in the central portion and becomes almost vertical at the north end of the area mapped. The strike of the beds at the north end is N. 10° W.; at the south end the strike becomes more nearly east and west, as the end of the basin is reached. The numerous sheets and dikes of quartz-bearing porphyry in this belt complicate the structure locally.

South of the divide, in the area covered by the Quartz Creek, Gold Brick, and Carbonate districts, there are two bodies of sedimentary beds, as shown in figure 1. The central or Pitkin area forms a basin (see section C–D and E–F, fig. 1), the beds dipping into it from all directions. Ohio Creek follows what is apparently the top of an anticline, cutting through the sedimentary rocks into the pre-Cambrian. The same rocks are exposed on both sides of the top of the valley walls, though the beds to the west are considerably higher

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than those to the east. The east side of this area fans out on the top of the west valley wall of the north fork of Quartz Creek, and the erosion of this stream probably accounts for the long tongue of the series that extends to the southeast. East of the north fork nothing but pre-Cambrian gneiss and granite is exposed to the top of the main range. A fault following Hall Gulch has repeated the series. To the north of this fault the sedimentary beds are exposed in the bottom of the valley, but to the south they lie near the crest of the ridge, about 900 feet above the stream. There is also a fault within the Pitkin lime belt, striking about parallel with the one just de-

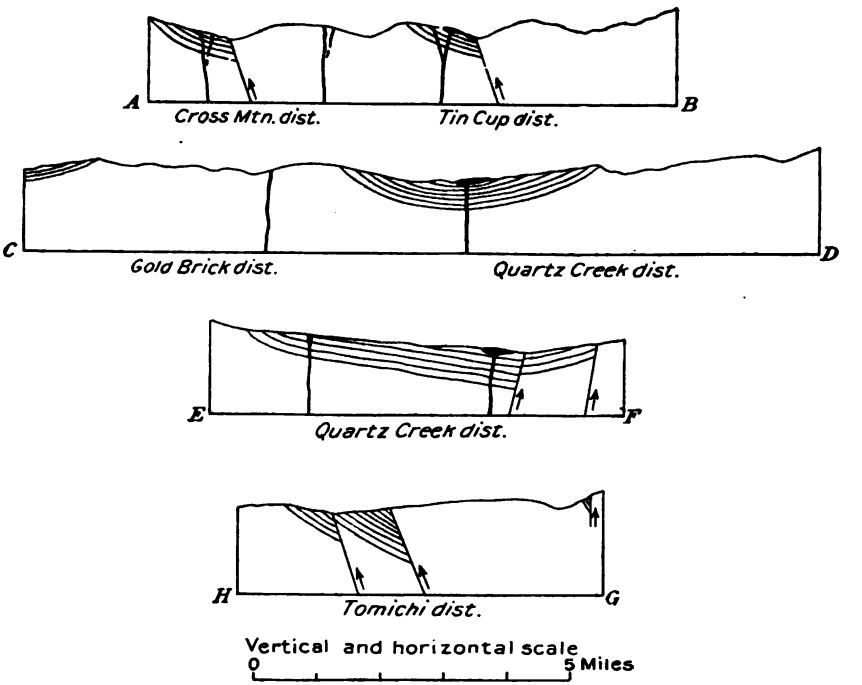

FIGURE 1.—Generalized structure sections in southeastern Gunnison County, Colo. For lines of sections see Plate I.

scribed. It is small and runs out in a low anticline before it reaches Armstrong Gulch. In this area there are several dikes and sheets of quartz-bearing porphyry, and one stock which stands up as a prominent knob on the divide between Hall and Armstrong gulches, about 1½ miles southeast of Fairview Peak.

The Tomichi district lies largely in the pre-Cambrian region and the structure is very complicated. The district includes two small areas of sedimentary beds. (See section H–G, fig. 1.) There are several dikes of granite porphyry, all of which have a general north-south trend and parallel the main structure of the gneiss and granite.

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Numerous small faults trending in the same direction are shown in the underground mine workings. The more prominent faults cut across the general structure and define the area of the sedimentary exposures. (See fig. 1.)

In all the pre-Cambrian areas indicated on Plate I the general structure of the granites, gneisses, and schists follows approximately north-south lines. This trend has determined in large measure the strike of the intrusive rocks, as they usually follow the general structure, and of the ore deposits of the pre-Cambrian areas, which occur almost invariably in small faults or slips, taking the form of lenses and veins with a north-south strike.

MINERAL RESOURCES.

HISTORY.

As early as 1875 mention was made by Raymond [a] of the discovery of silver ores "in the Uncompahgre, Gunnison, and Lake districts." In 1878 discoveries were made in the Quartz Creek district at the Silver Islet and Terrible mines, and at the Jimmy Mack mine south of Tincup. The years 1879 and 1880 witnessed the first rush of miners to southeastern Gunnison County, a large number of them coming from the Leadville district. They organized the towns of Pitkin and Ohio City early in 1879, and by the close of that year there were small villages at both places. It was not until 1880 that much work was done in the Tomichi district, and active development there did not begin until two years later. Most of the early prospectors departed, leaving a few who had faith in the discoveries to develop the mines. In 1882 a smelter was in operation at Virginia City, 2 miles north of Tincup, treating most of the ores of the Tincup and Quartz Creek districts. Later a small smelter was blown in at the forks of Tomichi Creek, 2½ miles south of White Pine, but met with little success. Both of these smelters have since been abandoned. By 1881 work in most of the camps was in full swing, and by 1883 the production of the districts was estimated by the Director of the Mint as follows: Tincup, $405,000; Tomichi, $400,000; Quartz Creek, including Gold Brick, $195,000. The statistics of the United States Geological Survey given in the annual volumes of "Mineral Resources," from 1903 to 1907, inclusive, show the production of the districts as follows:

Box Canyon: Gold, $1,351; silver, $35; most of this output being in 1906 and 1907.

Districts south of Tomichi Creek: Gold, $41,384; silver, $4,257. The mines of this district were most active in 1903 and 1906.

[a] Raymond, R. W., Statistics of mines and mining (eighth annual report), Washington, 1877, p. 284.

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Gold Brick: Gold, $79,074; silver, $20,043; lead, $6,082. The years 1906 and 1907 show the most production, though this district has been a constant producer since 1903.

Quartz Creek: Silver, $97,115; gold, $4,600; zinc, $3,452. From 1903 to 1905 the mines of the district were fairly active. In 1906 production fell off, and none of the mines were producers in 1907.

Tincup: Silver, $30,198; gold, $15,757; lead, $6,132. Up to 1906 silver was the chief metal saved; in that year, however, probably owing to improvements in treatment, the gold values show a big increase.

Tomichi: Lead, $19,314; silver, $13,219; copper and zinc, $10,642; gold, $1,638. This has always been a silver and lead district, though in 1903 and 1905 small quantities of gold were recovered.

GENERAL OUTLINE.

In the early days of mining in southeastern Gunnison County only the deposits in the sedimentary areas appear to have been worked. These are, as a rule, replacements in the dolomitic beds. They have the usual irregular distribution of such deposits, but appear to be dependent on the amount of disturbance, which is due either to faulting or to intrusion of the formations. The major part of the deposits of this class have their chief value in silver, which is accompanied by galena, gray copper, and sphalerite, all of the ore being more or less altered to carbonates. As would be expected where intrusive porphyries cut sedimentary formations, there is much alteration at the contacts; and in one place at least a marked contact-metamorphic ore deposit was seen. The ore shows galena, sphalerite, and chalcopyrite in a gray crystalline limestone altered to epidote.

What prospecting has been done in the pre-Cambrian rocks shows that the general structure has a north-south direction, that the deposits occur as quartz veins following fractures, and that the values are chiefly in gold, with some silver, found in a mixture of gray copper, chalcopyrite, galena, and pyrite.

At one place in the Green Mountain district a gold-bearing quartz-tourmaline vein was found in a pegmatitic granite of probable pre-Cambrian age, and there is some evidence that the deposit also is of pre-Cambrian age. In contrast to this is the fact that a gold and silver bearing vein of relatively recent origin is found in the pre-Cambrian near an andesite flow. This deposit is a vein of quartz, calcite, and fluorite, showing strongly marked crustification. It carries its values in a combination of chalcopyrite, gray copper, galena, and sphalerite.

There are probably at least three distinct ages of ore formation, grouped as follows:

1. Pre-Cambrian, as represented by a quartz-tourmaline vein in pegmatitic granite and possibly other deposits in the same vicinity.

2. Post-Carboniferous, and probably post-Cretaceous, as represented by: (*a*) Replacement deposits in dolomite; (*b*) contact deposits; (*c*) vein deposits in

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pre-Cambrian rocks following fault fissures. The deposits of the third class are closely related to intrusive porphyry.

3. Late Tertiary veins in pre-Cambrian rocks, showing crustification. These deposits appear to be connected with andesite flows.

DESCRIPTION OF DISTRICTS.

The mining districts of southeastern Gunnison County are, named from north to south, Cross Mountain, Tincup, Gold Brick, Quartz Creek, Gold Basin, Green Mountain, Cochetopa, Box Canyon, and Tomichi. In this report the detailed descriptions will be taken up in that order, except that the Gold Basin, Green Mountain, and Cochetopa districts will be discussed as one area, which, in fact, they are. The locations of mines and the boundaries of districts and sedimentary areas are shown on Plate I.

CROSS MOUNTAIN DISTRICT.

The mines of the Cross Mountain district lie principally on the east side of the ridge running northward from Fairview Peak beyond Cross Mountain, though there are some prospects east of Lottis Creek. The boundaries of the district are: To the south, the divide between Quartz Creek and Gunnison River, and to the east, the divide between Lottis and Willow creeks. The north and west boundaries are not known.

The eastern slope of the Fairview-Cross Mountain ridge is composed of the sedimentary beds, which dip eastward at relatively high angles and are cut off along Lottis Creek by a fault. The mines of this area were not visited; but it is stated that the ore is largely argentiferous galena, with its decomposition products. It is usually found in the dolomitic members of the section. East of this "lime belt" is an area about 3 miles in width, underlain by red granites and syenite and cut by a few porphyry dikes. In some places there are quartz veins, striking generally north and south, which carry values in gold, copper, and lead. Very few of these deposits have been opened by more than a 10-foot hole.

TINCUP DISTRICT.

Location and geology.—The Tincup district is bounded on the east by the Continental Divide, on the south by the Gunnison-Quartz Creek divide, and on the west by the Willow-Lottis Creek divide. To the north it now extends for at least 30 miles, the mines around Taylor Park and Italian Mountain being recorded in the Tincup mining district. Only the portion south of Tincup was visited by the writer.

The larger part of this area is underlain by pre-Cambrian gneiss and schist, though there are two areas of sedimentary formations.

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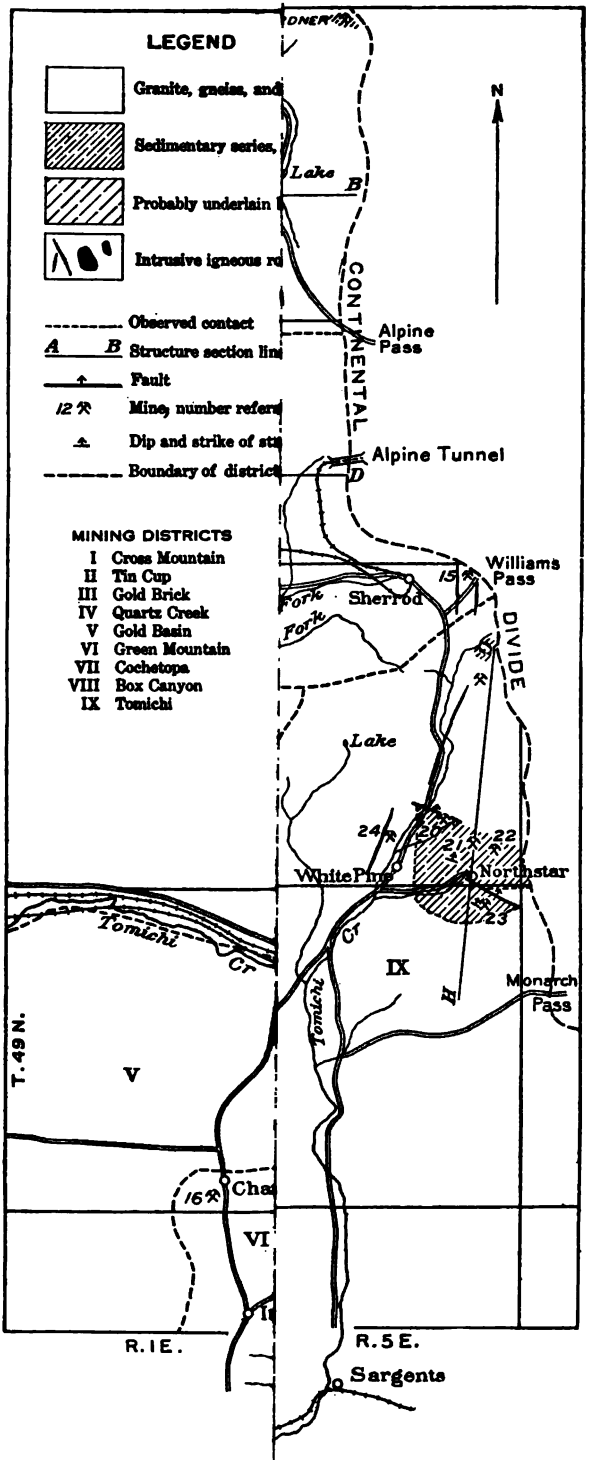

SKETCH MAP OF DISTRIBUTION OF

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An area west of the west fork of Willow Creek, as well as the east wall of its valley, is made up of red granite of coarse texture. At the crest of the east side of the valley at its south end is an outcrop of the basal quartzite, which strikes N. 10° W. and cuts across the west fork southwest of Tincup. The rocks above the quartzite are as follows, in ascending order:

Gray limestone containing white chert.
"Parting" quartzite.
Gray dolomite.
Yellow shales and limestone.
Very dark dolomitic limestone.
Massive blue limestone.
Carbonaceous shales.

These beds dip 45° E. about 1½ miles south of Tincup, 70° E. just west of the town, and about 20° a little to the northeast near the top of the east-west divide, which cuts off the formations on the south.

Included in this sedimentary area, as well as in the older formations, are a number of dikes and sheets of fine to coarse grained acidic porphyry. The composition of the groundmass in the fine-grained variety is difficult to judge, but it is provisionally called felsitic porphyry. The coarser porphyry is granitic, containing orthoclase, quartz, and biotite crystals of megascopic size. On the ridge road running southward from Tincup to Pitkin the best exposures of the rocks are seen. In several places dikes and other small bodies of intrusive rocks, as well as two sheets, have been cut in grading. One sheet, about three-fourths of a mile south of town, is a coarse-grained acidic porphyry. Near the crest of the divide is another sheet which is much finer grained, though it appears to have the same general composition.

Near the top of the main range, at an altitude of 12,000 feet, is the second body of sediments. It is about 3 miles east-northeast of Tincup, on the north fork of the east fork of Willow Creek, and is composed of highly metamorphosed quartzite and limestone, all of which are much iron stained. These rocks are probably of pre-Cambrian age.

Mines.—The principal mines of this district lie to the south of Tincup, in the sedimentary area. The ore is a gold and silver bearing galena with some stephanite(?) and forms a replacement deposit in the more dolomitic members of the sedimentary series. The gangue minerals are largely quartz and calcite, though in many places the metallic minerals are found without other gangue than dolomite. The surface ores are said to have been very rich in free gold. These free-milling deposits were soon exhausted, argentiferous carbonates and silver chlorides being the principal ores of the oxidized zone. These in turn gave place to the galena, gray copper, and pyrites which

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are being mined at present. Of late years more attention has been given to prospecting the gneiss and schist area north and east of the town. As a result of this work there have been some finds of lead-copper ores carrying gold. These ores are found in quartz-bearing veins which usually strike nearly north and south and fill small fault planes.

The only work that was being done in this district in July, 1908, was at the Blistered Horn tunnel, which starts into the east side of the west fork of Willow Creek about 3½ miles south of Tincup, to cut the workings of the Jimmy Mack property (1).[a] The shaft house of this mine is 1,500 feet above the mouth of the tunnel on the cropping of the ore. (See Pl. I.) The Blistered Horn tunnel starts in granite, but cuts the basal quartzite about 1,000 feet from the mouth. An upraise has been started to connect with the lower workings of the Mack. Entrance was not permitted, owing to the absence of the superintendent, the information given above being obtained from him after the field work was finished.

The Gold Cup, Tincup, and Drew mines (2) are all situated close together on the north slope of Gold Hill, about 3 miles due south of Tincup. All these workings were inaccessible on account of the bad air and accumulations of ice. So far as could be seen from the surface, the inclines follow the ore and dip about 30° to 35° ENE. The extent of underground working is not known. The ore seen on the dump is largely galena, with some pyrite and chalcopyrite, stained with lead and copper carbonates. From the rock on the dumps, together with that in the ore bin, it is judged that the deposits are largely in the dolomite, which lies immediately below the massive blue limestone. This fact, however, could not be verified by actual observation. The owners of the Gold Cup property have started a tunnel from the middle fork of Willow Creek to intersect their ore. This tunnel was over 800 feet in length, the first 100 feet cutting carbonaceous shales and the breast being in the massive blue limestone.

There are two mills in this district, both of which are on the west fork of Willow Creek. One, a concentrating plant, is at the Blistered Horn tunnel, and the other, a 90-ton cyanide mill, is below the West Gold Hill mine (3), about 2 miles southwest of Tincup.

GOLD BRICK DISTRICT.

Location and geology.—The Gold Brick district lies entirely within the Ohio Creek drainage area (see Pl. I), the rim of the basin forming its boundaries. The shipping and supply point is Ohio City, whence a good wagon road runs up Ohio Creek to the mines. The

[a] Numbers after names of mines correspond to those used on Plate I.

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entire area is in pre-Cambrian rocks. Red granites are exposed about Ohio City, but these give place to gneiss and schists about 3 miles north of the town. There are schists of various kinds, ranging from dark hornblendic varieties to those made up of light muscovite and quartz. The schistosity strikes N. 5° W., as do most of the faults and dikes.

The ore deposits are found in veins which range in width from a fraction of an inch to 4 feet, and which without noted exception parallel the dip and strike of the general structure of the schists and seem to follow zones of movement. The smaller veins contain gold and silver bearing lead, copper, zinc, and iron sulphides, with a very small amount of quartz and clay gangue. Many of the larger veins are filled with clay gouge, in which there are bodies of metallic minerals usually accompanied by granular quartz.

Mines.—At only two of the mines of this district was work in progress at the time of the writer's visit—the Sandy Hook tunnel and the Gold Links tunnel. The dump of the Cortland mine was, however, being milled at a plant located on Quartz Creek about a mile northeast of Ohio City.

The Sandy Hook tunnel (4) is driven into the west wall of Ohio Creek about 8½ miles north of Ohio City. The country rocks are schist and gneiss, intensely fractured in a north-south direction. About 200 feet south of the tunnel there is a 300-foot dike of coarse-grained granite porphyry which cuts across the valley in an east-west direction. The tunnel was 480 feet in length and was driven due west. In this distance two small veins of lead-zinc ore had been cut, and the breast was in a 2-foot seam of clay gouge that showed some galena and pyrite. The veins strike N. 5° W. and follow the schistosity, which coincides with the direction of the faults; it was noticed, however, that the veins widen somewhat and become richer to the south, near the intrusive. The ore is said to carry gold and silver. The metallic minerals are galena, sphalerite, and pyrite in a quartz gangue. A steam-driven air compressor supplies two air drills, and it was the intention of the owners to install a concentrating plant on the property at an early date.

The Gold Links tunnel (5) is driven 3,500 feet into the east wall of Ohio Creek about 7¾ miles north of Ohio City, just below a small branch of the stream which comes in from the east. The country rock is schist and granite. The tunnel cuts through dark schists for the most part, though it encountered two small bodies of granite and one dike of fine-grained white acidic porphyry which contained iron pyrites. The whole body of rock is intensely fractured in a north-south direction and many, though not all, of the faults are filled with ore. Six workable veins have been cut in the tunnel. These range from a few inches up to several feet in width. The smaller

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veins seem to be the richer and are filled almost entirely with galena, chalcopyrite, pyrites, and sphalerite in a fine quartz gangue. At one place in the tunnel a body of schist 20 feet wide contains, according to reports, enough sulphides to work as low-grade ore.

The company has two steam plants, one running compressors for the air drills and the other the concentrating mill. The mill is new, only 20 of the 50 stamps being in position. It was hoped, however, that all the machinery would be in place by the end of the summer. After the ore is sorted into smelting and concentrating grades at the top of the building the concentrating ore goes into storage bins on being rough broken by hand. There is a set of rolls for each battery of 10 stamps, the pulp from which passes over 12 feet of plate before it is conveyed to the eight Wilfley tables on the main floor of the mill. Most of the gold is saved on the plates, though the concentrates are said to contain some gold values as well as silver.

Other mines of the district which were closed down in July, 1908, are the Belzora Bassic tunnel (6), one-fourth of a mile south of the Sandy Hook tunnel, and the Carter tunnel (7) and Raymond Consolidated tunnel (8), both on Ohio Creek, south of the Gold Links. The Raymond Consolidated is the nearest to Ohio City. (See Pl. I.) At all these properties air is used for drilling, and at the Raymond and Carter there are small concentrating plants.

QUARTZ CREEK DISTRICT.

Location and geology.—The Quartz Creek mining district is bounded on the north by the ridge between Fairview Peak and the Continental Divide, on the east by the main range, on the south by Quartz Creek, and on the west by the divide between Armstrong Gulch and Ohio Creek. (See Pl. I.)

The general geology is shown on Plate I and figure 1. The Armstrong Gulch area is underlain by the sedimentary series described in detail on pages 24–25. East of the north fork of Quartz Creek pre-Cambrian gneiss and granite are exposed to the top of the main range. The mines of the district are, with a few exceptions, located in the "lime belt" exposed in Armstrong and Hall gulches; there are, however, some mines about 2 miles west of Sherrod, near the crest of the Continental Divide. The deposits within the sedimentary formations are replacements in the dolomitic beds; those near Sherrod are of recent origin and lie wholly within the pre-Cambrian rocks.

The sedimentary beds of the Pitkin region dip toward Armstrong Gulch from all directions, the basal quartzite being everywhere exposed on the outer rim. The dip varies from 30° around the edge of the area to 5° to 13° in the central portion. Ore is usually found in

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the dolomite which lies just below the "Fairview" shale, but is sometimes, though very rarely, encountered in the two upper dolomites—that just above the "buckskin" limestone and the dolomitic portion of the upper massive blue limestone. The croppings of the "Fairview" shale around this area have afforded the best opportunity for prospecting, and as a consequence most of the mines are located near the circumference of the basin. The exceptions are at points numbered 12 and 13 on Plate I. At 12 there is a small fault striking N. 60° W., which runs out into a low fold before it reaches Armstrong Gulch, and along which there has been some mineralization. At 13 a shaft was sunk through the undisturbed overlying formations in the hope of finding ore at the "Fairview" contact.

Mines.—At none of the mines of this district was work being done in July, 1908, except at the Red Jacket. Most of the mines have been closed for some time, and accumulations of water or ice, together with bad air, rendered access to them impossible.

The ore at all the mines is largely argentiferous galena, with possibly some stephanite, and gray copper. Wherever seen it is more or less stained with lead and copper carbonates. In some of the ore from the Fairview mine (9) kernels of crystallized galena were seen surrounded by a very fine grained dark mineral showing no crystal form, which reacts like galena but contains a large percentage of silver; this in turn is in many places surrounded by lead and copper carbonates. The ore bodies are very irregular and lie usually in the upper portion of the dolomite just under the yellow "Fairview" shale. They are often vuggy, exhibiting crystals of calcite and quartz on the drusy surfaces. The gangue is largely calcite and quartz, though numerous masses of ore have no other gangue than the dolomite.

The Fairview mine is 7½ miles a little west of north of Pitkin, on the divide between Armstrong and Hall gulches about 1½ miles southeast of Fairview Peak. It was worked by an incline said to be 800 feet deep, with levels every 100 feet. This incline dips 35° S., following the ore immediately under the "Fairview" shale. The first level is 70 feet below the surface. Most of the ore has been removed from it by overhead stoping, being sorted as mined, and the barren rock being used as filling. The mine has been closed for some years, and the incline below the first level is half full of ice, which made further exploration impracticable. All the machinery except the boiler has been removed, and the buildings are going to ruin very rapidly.

The Cleopatra lies just east of the Fairview on the same contact. The upper workings have been abandoned, however, as the company has a tunnel in Hall Gulch about 2,000 feet below the cropping. This

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tunnel could not be entered. Ore has been taken out through it, however, and some is still to be seen in bins and sacks at the entrance.

The Swiss Bell mine (10) is on the north side of Hall Gulch, about 2 miles from Quartz Creek. The ore here lies directly on the surface, in the dolomite in the upper portion of the massive blue limestone, where the beds are locally folded into a low anticline. The ore is very irregular in distribution, and as the old workings have followed it they are rather complicated; they consist of an incline and shaft which reach a depth of 100 feet. A new shaft about 500 feet north of these old workings has been sunk to a considerable depth, but no ore has been taken out of it. Water was standing well up in this shaft, so its depth could not be ascertained. It has two compartments and the rock was raised by steam hoist.

The Silent Friend (11) and Terrible (12) mines were not visited, as the workings were inaccessible. They are both worked by inclines, that of the former dipping to the west and that of the latter to the northwest on a fault.

The Silver Basin shaft (13) is said to be about 750 feet deep, having cut the "Fairview" contact. Whether ore was found is not certain. The statements of the mining men of the vicinity differ and the writer could not make a personal inspection, as the shaft is full of water.

The Red Jacket property (14) lies about three-fourths of a mile west of Pitkin and is opened by a shaft and tunnel. The shaft was full of water, but work in the tunnel was in progress on the "Fairview" contact. No large bodies of ore were visible, though there were some small pockets of galena exposed in the workings.

It seems to be the opinion of most of the prospectors at Pitkin that ore will always be found at the contact of the dolomite and the "Fairview" shale. This opinion, however, is not substantiated in all cases. One in particular came under the writer's notice. A tunnel driven into the east side of Armstrong Gulch to intersect the workings of the Terrible mine started near the bottom of the massive blue limestone and has cut all the formations, including the lowest (Silurian) limestone, which here dips about 13° SW., without finding any indications of mineralization.

REGION EAST OF SHERROD.

About 2 miles east of Sherrod siding, on the Colorado and Southern Railway, there is a group of mines situated on a small spur of the Continental Divide. The rock of the area is pre-Cambrian gneiss, capped at the top of the range by a dark-red, fine-grained rock, probably andesite, that is cut in at least one place by an acidic porphyry dike, which strikes north and south. The ore from these mines is a silver and gold bearing lead, zinc, and copper sulphide

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found in veins containing quartz, calcite, and fluorite. The veins strike a little east of north, show marked banded structure due to deposition, and are probably the most recent deposits in the region described in this report.

The N. B. C. mine (15) is on the north side of the spur about 2 miles by road from Sherrod. It is opened by a tunnel, which was 180 feet long at the time of visit. The vein for which the operators were driving had not been cut, but they hoped it would be found within the next 50 feet. The croppings of the vein above the workings stand out fairly well but do not show much mineralization other than quartz, calcite, and fluorite having a distinctly banded structure.

The Brittle Silver mine is on the west slope of the ridge, about half a mile north of the N. B. C. workings. It has not been in operation of late and as no one with authority was on the ground it could not be examined.

DISTRICTS SOUTH OF TOMICHI CREEK.

There are two districts south of Tomichi Creek, the Gold Basin and Cochetopa, within which a small area around Iris and Chance has been set aside as a separate mining district called Green Mountain. The rocks of this area are entirely red and gray granite and gneiss. Within this main body are what appear to be segregations of the ferromagnesian minerals, many of which closely resemble dikes in form. The granite is usually coarse textured and in some places is rather pegmatitic.

Most of the mines are situated about the towns of Iris and Chance, but there are a few near Sillsville. Nearly all these mines are abandoned, the only one in all this area that was open at the time of visit being the Lucky Strike mine (16), south of Chance. This mine is opened by two shafts, one equipped with a steam hoist and the other with a whim. The main shaft has only one compartment and is about 200 feet deep, with the first level 80 feet below the collar. Most of the ore has been stoped out above this drift, though at present ore is being taken from approximately the same level at the second shaft, 600 feet farther northwest. The ore found in a vein 2 to 4 feet in width, which strikes north of east and dips to the southwest, consists of massive iron-stained to white quartz containing tourmaline. The inclosing rock is gneissoid and locally shows good walls, though in many places the dividing line between ore and barren rock can not be determined. A segregation of orthoclase feldspar crystals, resembling a vein striking parallel with the ore body, is exposed about 300 feet northeast of the vein and can be traced by its outcrops for a considerable distance. A crusher and 5-stamp mill, situated just north of the main shaft, reduce the ore, the values being saved

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on an 8-foot amalgamation plate. The tenor of the ores is reported by the operators to be from 1 to 2 ounces per ton, of which 90 per cent is saved. The waste pulp contains a small amount of copper and possibly a little tellurium.

The Maple Leaf mine (17), near Sillsville, was closed in the latter part of July, 1908, so that access to the works could not be obtained. The ore is said to be a free-milling massive quartz containing both gold and silver, found in veins in a coarse dioritic rock. The veins strike almost east and west.

BOX CANYON DISTRICT.

The Box Canyon district is bounded on the north by Quartz Creek, on the south by Tomichi Creek, and on the east by the divide between Tomichi and Hot Spring creeks. The southwestern portion of this area is probably underlain by the sedimentary formations which are exposed on the flanks of Tomichi Dome and north of Wanita. In the area north of Bowerman are exposed mica schists having a general northwest-southeast strike, included in which are lenses of diorite paralleling the schists. The mines of the district are north of Bowerman, the usual ore being a free-milling quartz, though it is said that a copper deposit has been found at the Abe Lincoln tunnel, just north of the town.

The Independence mine (18) is 3½ miles southeast of Pitkin and about the same distance northeast of Bowerman. It has been abandoned for several years, as the deposit was entirely exhausted. The ore body was a lens of mica schist seamed and veined with quartz containing free gold. The deposit was worked by a shaft which ran out of the ore at a depth of about 80 feet. Two tunnels were driven in below the shaft, and though quartz stringers were found no values could be obtained.

The Camp Bird mine (19) is 1½ miles northwest of Bowerman. The ore is a free-milling quartz, somewhat iron-stained and honeycombed, found at the contact of lenses of diorite and mica schist. The two-compartment shaft is said to be more than 100 feet deep. A bucket hoist is used to raise the ore, which is sorted at the mine and transported by wagon to a 10-stamp mill below Bowerman.

TOMICHI DISTRICT.

Location and geology.—The Tomichi mining district is bounded on the west by the divide between Tomichi and Hot Spring creeks, on the north by the divide between Tomichi and Quartz creeks, and on the east by the main Sawatch Range. White Pine, the only town in the district, is nearly deserted, as very little in the way of mining operations is being done. The southern and western parts of the district are largely occupied by red granite. North of the forks of Tomichi

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Creek gray granite and gneiss are found to the top of the Continental Divide, except for the two small areas of sedimentary beds shown in section H–G, figure 1, and on Plate I. These beds are very much altered and little could be determined as to their correlation with the sections at Pitkin and Tincup. The general structure of the granitoid rocks trends north and south and is marked by many faults, seen in the underground workings, and by several dikes of quartz-bearing porphyry. There are, however, two marked faults just east of White Pine, striking northwest and southeast, that determine the form of the small sedimentary area where the principal mines were located.

Mines.—The Parole tunnel and Spar Copper shaft (20) are situated about half a mile northeast of White Pine; the former is about 900 feet below the latter and starts about 900 feet west of it. The shaft is just north of the limestone-granite contact on a group of veinlets which are cut in the tunnel about 900 feet from its mouth. This tunnel starts in limestone, but cuts the contact about 800 feet from the mouth, running through barren gray granite for 100 feet to the veins. The ore is largely gray copper and chalcopyrite, though some galena is seen in veins which strike approximately north and south. The chief values are in gold and silver.

The Silver Trowel tunnel (21) lies about 1¼ miles east of White Pine, on Galena Creek, a little west of the center of the sedimentary area. The beds dip from 30° to 45° N. and strike a little north of east. The tunnel is about 120 feet long and cuts near the mouth a dike of granite porphyry which strikes N. 10° W. Beyond the dike is a gray crystalline limestone resembling marble, which has been altered to almost pure epidote near the dike. Ore is found in the altered portion next to the unaltered limestone; it consists of galena, sphalerite, and some chalcopyrite, and carries silver and gold.

The Eureka incline (22), located about three-fourths of a mile southeast of the tunnel last described, follows the contact between quartzite and blue limestone, which dips to the north at 20° to 45°. It is about 400 feet deep, with 100-foot levels. The surface ore was largely lead carbonate, which gave way to galena with depth, and had almost no zinc. It is a typical replacement deposit at the juncture of limestone and quartzite.

The Morning Star mine (23) is just south of the small fault shown on Plate I. This fault cuts the sedimentary area, giving a granite hanging wall and a limestone foot wall for the ore, which is a combination of lead and zinc sulphide.

West of White Pine the ridge between the two forks of Tomichi Creek is composed of gray granite severely faulted along lines striking a few degrees east of north and intruded by dikes of granite porphyry that parallel the faults. There are several mines along the line of most intense disturbance, about one-half mile west of town, at

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which the ore is said to consist of copper and lead sulphides carrying gold and silver. The ore occurs in veins that fill fault planes. The chief mines here are the Silver Cord, Lily, and Alice. The Alwilda tunnel (24) one-fourth of a mile north of White Pine, crosscuts the granite and opens the extension of the Silver Cord vein, which is here about 10 inches wide and contains gray copper, chalcopyrite, and galena in a quartz gangue.

On Tomichi Creek there are two small deposits of iron, both located north of White Pine, one half a mile and the other 1½ miles up the creek. The latter is a flat-lying body from 1 to 1½ feet thick, occupying a flat above an old beaver dam. The former deposit is exposed by an open cut and tunnel about 200 feet above the bottom of the valley on the east wall at the fault contact of the larger sedimentary area and the granite. Here there are two belts of magnetite separated by about 50 feet of altered limestone. The northern body lies against gray granite. It is 50 feet wide and not so rich as the southern one, which is 15 feet wide and lies on top of an unaltered gray limestone. This limestone contains white chert, which greatly resembles the Silurian(?) limestone of the Pitkin area. A small amount of this ore was mined for use as flux at the old smelter, 5 miles down the creek. Since that smelter has been out of use nothing has been done with the deposit, as it is too small to pay for the heavy transportation charges.

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THE HORNSILVER DISTRICT, NEVADA.

By FREDERICK LESLIE RANSOME.

The town of Hornsilver, which came into existence in 1907, lies in Esmeralda County, Nev., 26 miles south-southwest of Goldfield, 14 miles southwest of Cuprite (a station on the Las Vegas and Tonopah and the Tonopah and Tidewater railroads), and 12 miles southeast of Lida. Mining in this vicinity is not wholly recent, and an earlier settlement on the site of Hornsilver was known as Lime Point. Prospecting in this region began about 1868, and over twenty years ago ore was hauled to a mill near Lida from the Grand Central and other claims near Lime Point; but most of these claims had long been abandoned when the growth of Tonopah and Goldfield called attention anew to this part of Nevada and provided better facilities than formerly existed for its economic development. Work on the Great Western vein began in 1905, and the Grand Central was relocated early in 1908, after the presence of rich ore in the Great Western had been established.

The following notes are based on a visit of a day's duration in June, 1908. At that time there were about 500 people in the district and considerable prospecting by lessees was in progress in the hills west and south of the town. Water was hauled from a spring 12 miles away and supplies were brought from Goldfield by wagons or partly by rail by way of Cuprite. One mine only, the Great Western, was shipping ore.

Hornsilver, at an altitude of 5,900 feet, lies on a gentle alluvial slope, which opens northward into one of the broad desert valleys common in the region and is inclosed on other sides by hills rising from 500 to 1,000 feet above the town.

The rocks of the district are limestones and calcareous shales, which are intruded and in places more or less metamorphosed by masses of granite. The stratified rocks are mapped by S. H. Ball[a] on his reconnaissance map as the Prospect Mountain limestone,[b] of Cambrian age. He described briefly[c] the rocks of Slate Ridge, south of the

[a] A geologic reconnaissance in southwestern Nevada and eastern California: Bull. U. S. Geol. Survey No. 308, 1907, Pl. I.

[b] Now known as the Eldorado limestone.

[c] Op. cit., pp. 182–195.

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new town, and shows that these old stratified rocks are continuous with the more metamorphosed beds at Tokop and Gold Mountain, southeast of that ridge.

Near Hornsilver some shale is interbedded with the limestone, but a considerable thickness of shale with subordinate calcareous beds underlies fairly massive limestone, which is exposed in the hills south and east of town. The ores lie mainly in these shales.

The principal veins are southwest of town, within a distance of a mile. They constitute an approximately parallel system and cut across the bedding of the shales with a prevailing strike of N. 55° to 60° W. and with steep dips. Although the wall rock is generally shale, the veins are parallel to some fine-grained and rather obscurely exposed dioritic dikes. The two principal veins are the Great Western and Grand Central, which are about a quarter of a mile apart, the Grand Central being the farther from town. These have been traced by trenches and pits for distances of 3,000 to 4,000 feet along their not very conspicuous outcrops. There are also three or four other veins on which less work has been done.

All of the vein material that could be seen in 1908 was thoroughly oxidized and for the most part soft. The fissures after being filled with quartz and sulphides evidently had been crushed by later movement along the original dislocation and the vein was thereby rendered specially permeable to oxidizing solutions. The valuable constituents of the deposits are native gold and chloride of silver.

The Great Western mine at the time of visit was developed to a depth of 200 feet and equipped with a 15-horsepower gasoline hoist. The 100-foot level was about 600 feet long and the 200-foot level about 175 feet long. Since that time a 300-foot level has been opened. The gross product of the mine in June, 1908, was, according to the owners, between $30,000 and $40,000, the shipments ranging in assay value from $75 to $400 a ton.

The Great Western vein strikes N. 60° W. and near the shaft dips 50° NE. At the northwest end of the 100-foot level, however, the vein is nearly vertical. There is a very regular and persistent hanging wall with a thin skin of soft gouge separating ore from country rock. The vein is in some places about 20 feet wide and consists of the usual crushed rusty quartz found in the veins of this district. Much of this material is said to yield assays of about $30 a ton, but only the higher-grade portions have been stoped. The ore from these portions shows abundant cerargyrite as sparkling olive-green crusts on the rusty quartz fragments and as small crystals in spongy limonitic material residual from the oxidation of the original sulphides. Minute quantities of a bluish-green mineral in thin crystalline rosettes associated with the cerargyrite are probably embolite or bromyrite but have not been chemically tested. The ore shipped in 1908 con-

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tained relatively little gold—not more than 15 per cent of the total value of the precious metals present. Recent reports, however, indicate that ore with a much higher proportion of gold has been stoped in the northwestern part of the 200-foot level.

A second vein has been cut near the shaft on the 100-foot level, samples from which were said to contain more gold than silver. It had not been stoped at the time of visit. In January, 1909, the mine was reported to be shipping 12 tons of ore a day by way of Cuprite.

A short distance southeast of the Great Western mine the vein passes under alluvial material and little is known of its extent or value in that direction. It has been traced northwestward, however, for 3,000 feet or more and several sets of lessees were engaged in 1908 in exploring this vein or others in the same general zone of fissuring.

No work was in progress on the Grand Central vein in June, 1908, although some shipments have since been reported in the mining press.

About 1½ miles due south of Hornsilver, on the other side of the limestone ridge (Slate Ridge), which separates the town from a small arm of Death Valley, known as Oriental Wash, is the Redemption mine, worked superficially many years ago and recently reopened by lessees. There are two adjacent parallel veins in limestone, striking about N. 40° E. and standing nearly vertical. These veins are opened by small tunnels and shallow winzes. The ore is partly oxidized galena and contains massicot, cerusite, wulfenite, and probably some cerargyrite. The greatest width of ore observed is 1 foot. The lessees, who were concentrating this material by hand jigging, stated that the best of the concentrates carry 40 per cent of lead, 30 per cent of zinc, and 40 ounces of silver to the ton. No zinc minerals were observed in the ore, much of which is soft and earthy.

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ROUND MOUNTAIN, NEVADA.

By Frederick Leslie Ransome.

A few hours were spent at Round Mountain, Nev., on June 29, 1908, and the following notes are based upon the necessarily hasty examination possible in so short a visit. The town of Round Mountain, which contains from 500 to 600 people, is in Nye County, 45 miles (about 70 miles by road) north of Tonopah and nearly the same distance south of Austin. It lies on the east side of Big Smoky Valley at the base of the Toquima Range, being 12 miles north of Manhattan and 3 miles southwest of the abandoned mining camp of Jefferson. Further details regarding the surroundings of the district may be had from the Tonopah topographic sheet of the Geological Survey, and a good general description of the camp has been published by George A. Packard.[a]

The town takes its name from a small oval hill of rhyolite which rises about 400 feet above the alluvial slope of the valley's edge. There is abundant water for all ordinary purposes, a supply from Shoshone Creek, east of town, having been made available by an outlay of $65,000.

The rhyolite of Round Mountain is generally fresh, with abundant phenocrysts of quartz and feldspar, up to about 5 millimeters in diameter, in a light-gray lithoidal matrix, which, as a rule, shows some flow structure. No microscopical study has been made of this rock, but it appears to be a normal rhyolite with orthoclase (sanidine) as the principal feldspar. According to Mr. Packard, granite has been found underlying the rhyolite near the saddle connecting Round Mountain with the main range east of it, and some shafts east and northeast of the hill are said to show slate and quartzite.

The only mine examined during my visit was the Sunnyside, on the south slope of Round Mountain. This, the principal mine of the district, is worked through a 35° shaft to a depth of 550 feet, measured on the incline. The levels are 50 feet apart and explore the vein for a length of about 300 feet. Although the general strike of the vein is nearly east and west, the levels, which are driven on the ore, all show sharp curvature, as illustrated in figure 2, so that the strike

[a] Round Mountain, Nevada: Min. and Sci. Press, June 13, 1908, pp. 807–809.

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of the deposit at different places may vary by as much as 90°. The ore body is fully 300 feet long and from 6 to 20 feet in width as measured in horizontal planes and extends from the surface to an unknown distance below the bottom level. The dip varies from 35° N. at the surface to 20° N. on the 550-foot level.

The ore is all oxidized and carries, on an average, from $10 to $15 in gold to the ton. Ore worth $25 a ton is exceptionally good. Although the deposit has been referred to as a vein, it is not really of that class. It is a mass of jointed and irregularly cracked rhyolite, somewhat stained with iron oxide, but showing no conspicuous alteration and no evidence of extensive movement. In most places the ore is separated from the country rock of the hanging wall by a close fissure or joint, the difference between ore and waste being not, as a rule, evident to the eye. Such a joint, when followed along the strike, is found to pass at some point into the ore or into the country rock, and another one of slightly different strike takes its place as a working boundary to the ore. The hanging wall is thus defined by a series

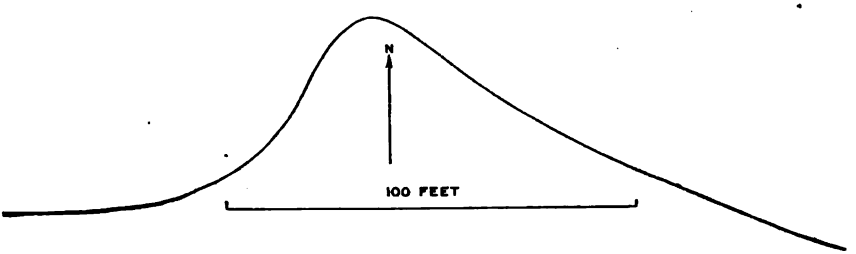

FIGURE 2.—General plan of a level in the Sunnyside mine, Round Mountain, Nev., showing the curved strike of the deposit.

of joints that intersect or meet at large angles. The distinction between ore and country rock is less definite on the foot-wall side of the deposit. On the whole, the limits of the ore body must be determined by panning or assaying and are not certainly recognizable from structure or appearance.

The value of the ore is practically all in gold, which is readily amalgamated. The mill, equipped with two Nissen stamps, two Huntington mills, and a tube mill, treats about 100 tons a day and extracts 92 per cent of the gold. Some coarse gold is found, associated with limonite in crevices in the rhyolite, but in most of the ore none of the metal is visible. No pyrite was seen in any of the ore, although a little was noted disseminated in the rhyolite at one place on one of the lower levels. In 1908 the mine, according to Mr. J. P. Loftus, president of the company, was producing from $35,000 to $42,000 a month. Steam power is used. The fuel is wood from the Toquima National Forest, purchased at $1.25 a cord and cut and delivered at a total cost of $8 to $10 a cord.

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A few hundred yards west of the Sunnyside mine some lessees have a shaft 200 feet deep on what is probably a continuation of the same deposit. At the time of visit they were hoisting $15 ore, which was hauled to a mill near town and there treated at a total cost of $7 a ton.

West of this lease, near the west end of the hill, is the Sphinx mine, 200 feet deep, and probably also on the same zone of mineralization. The ore at the time of visit was similar to that of the Sunnyside mine but of lower grade, the average value being a little less than $10 a ton. About 25 tons a day are treated in a Huntington milling plant with no stamps.

The Fairview and Daisy mines, east of Round Mountain, were producing in 1908, but were not visited. Their ore is said to lie in rhyolite and to be similar in general character to that of the Sunnyside. The Fairview has a 20-ton mill on Shoshone Creek, a mile northeast of town.

A notable feature of the south slope of Round Mountain is the wide distribution of the gold. Along the whole south base of the hill the superficial detritus or wash carries gold. This material, which consists of angular fragments of rhyolite of all sizes up to a few feet in diameter, with more or less earth and sand, has a maximum thickness of about 10 feet. It shows only traces of rough stratification and has accumulated by general creep down the slope accelerated by occasional heavy rains. At the base of the hill the deposit thickens and merges with the general wash of Great Smoky Valley. Hydraulic operations are confined to the hill, where the bed rock is within reach and where there is sufficient fall for sluicing. The gold is distributed through the deposit from top to bottom. When the rhyolitic bed rock is exposed it is found to be covered in many places with a firm crust of buff-colored calcium carbonate up to an inch in thickness. This adheres strongly to the fresh surface of the rhyolite as a rough, travertine-like crust and in places carries enough gold to make its removal by blasting profitable, especially as considerable gold is carried also in the superficial cracks of the rhyolite.

Two monitors were playing in June, 1908, and the washing, according to Mr. Loftus, was yielding about $20,000 a month. The water, however, was getting rather low and it was not possible to keep both streams in continuous operation. Prior to the use of water, gold to the value of $39,128 was obtained with two dry-washing machines. The ground worked by this method is said to have averaged over $5 a yard.[a] The gold is generally rather fine, but some nuggets of fair size have been found.

A large part of the rhyolite on the south side of Round Mountain, both under the wash and higher up the slope, contains considerable

[a] Packard, G. A., op. cit., p. 809.

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gold, partly in visible joints or small fissures, and partly in rock which is not noticeably fractured. Where the joints are close together and the rhyolite between them rather soft and decomposed, assays as high as $250 to the ton are said to have been obtained from samples taken near the surface; and from solid blocks of unfissured rhyolite assays up to $4 a ton are reported. How far this gold represents mere superficial enrichment is still an unsolved problem. In 1908 prospecting was in progress to determine whether or not extensive masses of rhyolite on the south side of the hill can be worked by an open-cut method for the gold scattered through the rock.

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MINERAL RESOURCES OF THE GRANTS PASS QUADRANGLE AND BORDERING DISTRICTS, OREGON.

By J. S. Diller and G. F. Kay.

GEOGRAPHY AND GEOLOGY.

By J. S. Diller.

INTRODUCTION.

The region considered in this paper is in southwestern Oregon. As shown on the accompanying map (Pl. II), it extends from the neighborhood of Grants Pass on the north to the State line on the south, and from Illinois River on the west nearly to Jacksonville on the east. It is mainly the country drained by Applegate River, and may be conveniently referred to as the Applegate region. It has an area of approximately 1,000 square miles.

Although the principal line of travel across the area had been previously examined, by far the greater part of the work, on which this paper was based, was done in the summer of 1908. I studied the general geology, assisted by James Storrs, who searched for fossils, and Prof. G. F. Kay examined the mines which he describes in the second part of this report.

For the Grants Pass quadrangle we had a good topographic map on the scale of about 2 miles to an inch, but for the border land on the east, west, and south the available maps were on a much smaller scale. On account of the large size of the area to be covered and its complicated structure it was not possible to examine the region in sufficient detail for final mapping.

GEOGRAPHY.

The Siskiyou Mountains of southwestern Oregon and the Salmon, Trinity, South Fork, and North Yolla Bolly Mountains of northwestern California all belong to the same group, to which some years ago the late Maj. J. W. Powell, then Director of the United States Geological Survey, gave the name Klamath Mountains. This is not only a very convenient but an appropriate term and is coming into general use. The Klamath Mountains lie at the meeting point of the

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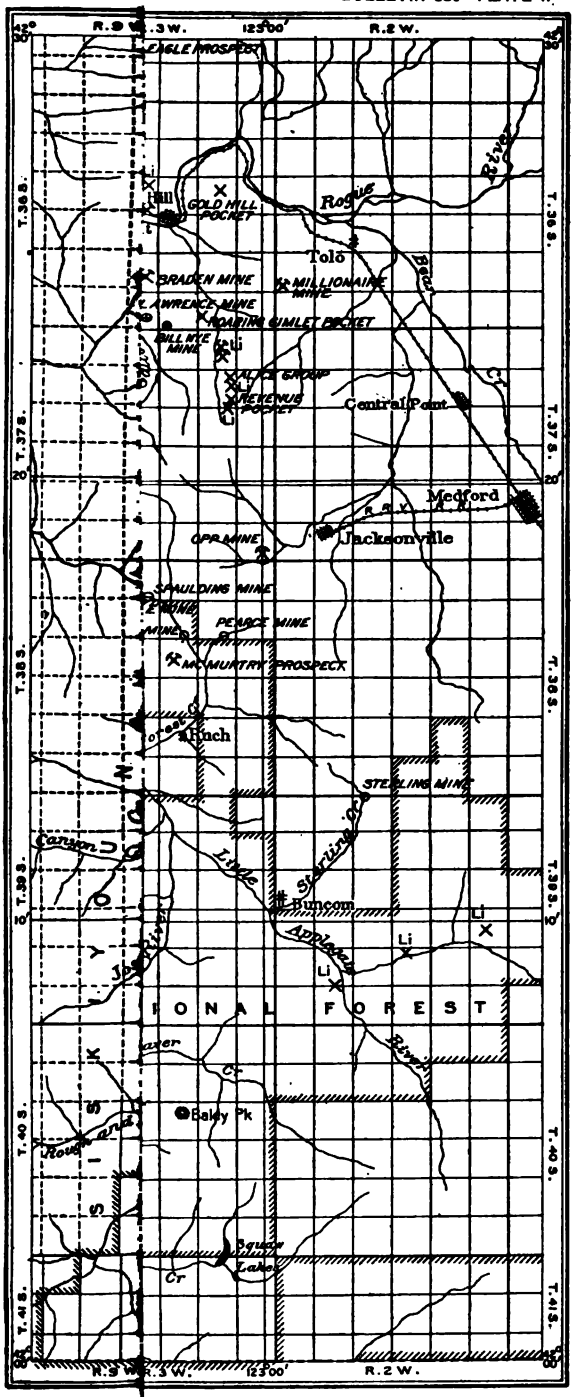

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MINING DISTRICTS, OREGON.

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Sierra Nevada, the Cascade Range, and the Coast Range. They are most closely related in position and structure to the Coast Range, but the kinds of rocks of which they are made up are like those of the Sierra Nevada.

The region under consideration lies within the Klamath Mountain group and extends from the crest of the Siskiyou Mountains northward to Rogue River, where the stage road and the Southern Pacific Railroad afford a convenient outlet for transportation. Applegate River, which heads in the Siskiyou Mountains, has carved out an irregular but in many places broad and fertile valley across the region. A stage mail route follows the Applegate to the crest of the Siskiyou Mountains in California, but there is no outlet to the south.

The region is mountainous and ranges in altitude from about 871 feet to over 7,043 feet above the sea. The fertile valleys are farmed and the mountains are generally well forested, especially in the southeastern portion, which belongs to the Siskiyou National Forest.

GEOLOGY.

GENERAL OUTLINE.

The rocks of the Applegate region include both sedimentary and igneous rocks of various types and ages. They are arranged in irregular elongated patches or bands running northeast and southwest diagonally across the Grant Pass quadrangle, and the igneous rocks occupy by far the larger portion of the area.

The sedimentary rocks are mainly Paleozoic (Devonian, probably with some Carboniferous), though there are a few of Tertiary age and some of Cretaceous. Besides these there is a mass of mica schists near the crest of the Siskiyou Mountains that appears to be older than the Paleozoic rocks of the same region.

The igneous rocks are in part intrusive, but many of them, possibly the greater portion, are volcanic.

MICA SCHIST.

Mica schist appears to be among the oldest rocks of this portion of Oregon. It occurs in a large area about Squaw Lake, in the southeast corner of the Grants Pass quadrangle, where it is associated with hornblende and chlorite schists. The last two are probably derived from the alteration of ancient igneous rocks, but the origin and age of the mica schist here referred to are not definitely known. Its nearness to the large mass of granodiorite that forms the core of the Siskiyou Range suggests that it may be due to the contact metamorphism of Paleozoic sediments by the granodiorite. However, the absence of andalusite and other characteristic contact minerals favors the view that the mica schist is older than the Paleo-

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zoic rocks of that region and lies unconformably beneath them. It is typical mica schist for the most part, with numerous leaves and veins of quartz and locally considerable pyrite.

PALEOZOIC ROCKS.

Kinds of rocks.—The Paleozoic sediments consist of clay slates, dark, siliceous, locally banded slates, and greenish slates, interbedded with tuffs and lentils of limestone. Near the contact with granodiorite they are locally metamorphosed into fine-grained mica schist, which usually contains characteristic minerals, such as chiastolite and staurolite.

Distribution of limestone.—Limestone is one of the most important Paleozoic sedimentary rocks of the region from an economic point of view, especially on account of its relation to the cement industry, and more of it occurs in the Grants Pass quadrangle than in any other quadrangle of equal size in western Oregon.

Measured directly across the strike the area occupied mainly by Paleozoic rocks, both sedimentary and igneous, in the Applegate region has a width of nearly 30 miles, in which there are four more or less clearly defined belts of limestone containing about 50 masses, most of which are located on the accompanying map as quarries or prospects. The largest outcrop is not over one-third of a mile in length and 200 feet in thickness.

The first belt of limestones includes prominent ledges 3 miles southeast of Kerby, as well as several on Cheney Creek, where they occur under favorable conditions for handling and getting to Grants Pass by a haul of 12 miles.

The second belt is less regular. It extends from the vicinity of Gold Hill southwestward by the Oregon Bonanza mine to the Oregon Caves and beyond into California.

The third belt, with several readily accessible ledges on Kane Creek, appears to the southwest on Applegate River, on Steamboat Creek, and in the vicinity of Whisky Peak, where the belt enters California.

The fourth belt of limestone appears on Little Applegate River, and possibly also on Applegate River near Watkins, where a prominent limestone ledge occurs close to the mica schist, which it appears to overlie.

Age of limestone.—The limestones at a number of points are fossiliferous, but the fossils are too poorly preserved to permit definite determination. In two lots—one from the Happy Camp trail, 10 miles south of Waldo, and the other from sec. 19, T. 37 S., R. 6 W., about 10½ miles southwest of Grants Pass—corals are abundant, and among them E. M. Kindle recognizes with doubt forms that he com-

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pares with *Favosites nitella* and *Cladopora robusta*, as well as a gasteropod resembling *Loxonema bella*. Mr. Kindle remarks that if these determinations are correct the beds represented are of Devonian age. It thus appears that the Cheney Creek and Gold Hill belts of limestone (the first and second noted above) are of Devonian age. A striking feature that occurs locally in some of the limestone ledges of the second belt is the inclosure of vesicular volcanic fragments, which indicates that volcanic eruptions occurred in the region at the time the limestones were forming.

In the third belt of limestone, which outcrops along Kane and Steamboat creeks, the only fossils found were fragments of round crinoid stems; the fourth belt, on Little Applegate River, contains both round and pentagonal crinoid stems well preserved. The general absence of other fossils from these two belts suggests a difference in age from the Devonian, and it is probable that they are either Carboniferous or Triassic.

Composition of the limestones.—For the purpose of showing the adaptability of these limestones to the manufacture of cement the following analyses were made by R. C. Wells in the chemical laboratory of the United States Geological Survey at Washington:

Analyses of limestone from Grants Pass quadrangle, Oregon.

	Sec. 19, T. 37 S., R. 6 W.	Carter's quarry, sec. 2, T. 37 S., R. 3 W.	Householders' quarry, sec. 2, T. 37 S., R. 3 W.	Ridge 1 mile southwest of Gold Hill, sec. 20, T. 36 S., R. 3 W.	Marble southwest of Williams, sec. 31, T. 38 S., R. 5 W.	Sec. 7, T. 41 S., R. 4 W., on Applegate River south of Watkins.	Three miles S. 70° E. of Kerby.
Specimen No	7015A.	7017A.	7017B.	7021	7025	7045	7074
Calcium oxide (CaO)	55.28	55.71	55.34	41.83	55.55	55.05	55.38
Carbon dioxide (CO_2)	43.57	43.54	43.23	32.57	43.63	43.25	43.51
Water (H_2O)	.50	.37	.56	.46	.26	.50	.40
Silica (SiO_2)	.23	.37	.31	23.86	.13	.53	.06
Alumina and iron oxide ($[Al, Fe]_2O_3$)	.28	.20	.44	.32	.38	.52	.62
Magnesia (MgO)	.03	.01	.03	Trace.	None.	Trace.	Trace.
	98.89	100.20	99.91	99.04	99.95	99.85	99.97

With the exception of No. 7021, these limestones are nonmagnesian and pure, and are well suited for the manufacture of cement. Shales that appear to be suitable to combine with the limestone to make cement occur convenient to the railroad in the Bear Creek portion of the Rogue River valley.

Relation of Paleozoic to adjacent rocks.—The succession of sediments included in the four belts of limestone and associated rocks, to judge from their attitude and distribution, appears to be conformable throughout, although these strata are apparently unconformable not only with the underlying mica schists but also with the overlying Jurassic rocks.

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JURASSIC ROCKS.

The Jurassic rocks of this region consist mainly of shales and thin-bedded sandstones in variable proportion. Small beds of fine siliceous conglomerates are rarely present. The shales are dark, locally black, but weather gray, yellowish, or brown, and here and there are decidedly slaty. The sandstones are gray and hard. Locally in the sandstones quartz veins are abundant, but usually they are scarce or absent. The fine conglomerate of quartzose pebbles contains, on its weathered surface, small cavities from which soluble pebbles have disappeared. Near the contact with granite these rocks are, in places, altered to mica schist. They occupy only a small portion of the region under consideration, in the vicinity of the stage road from Wilderville to Kerby, and their distribution indicates that they unconformably overlap the Paleozoic rocks.

CRETACEOUS ROCKS.

The Cretaceous rocks are comparatively soft conglomerates, sandstones, and shales that once formed a conspicuously unconformable blanket-like covering over a large part of the region, but erosion has removed all of it excepting a few small patches that cling on the older rocks in the neighborhood of Jacksonville and Waldo, where the conglomerate at the base is locally auriferous and mined as a placer.[a]

That these auriferous conglomerates are Cretaceous (Horsetown and Chico) is clearly shown by the fossils contained in the overlying sandstones and shales.

TERTIARY ROCKS.

The Rogue River valley contains a mass of soft sandstone of Tertiary (Eocene) age. It is decidedly arkose near the base and, lying between the Cretaceous strata on the west and the lavas that make up the Cascade Range on the east, it contains the beds of coal best exposed in the vicinity of Ashland and Medford.

IGNEOUS ROCKS.

In the Applegate region igneous rocks are much more abundant than sedimentary rocks and are of comparatively few types, embracing greenstone, serpentine, granodiorite, dacite porphyry, and augite andesite.

The rocks included under the general term greenstone are of several different kinds, but for the most part they agree in being

[a] Lindgren (Am. Jour. Sci., 3d ser., vol. 48, 1894, p. 275) describes an auriferous conglomerate of Jurassic age in the Sierra Nevada of California, and Turner notes one of Chico age in Oregon.

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much altered and greenish in color. When fresh and fully crystalline the greenstone is commonly like a gabbro composed essentially of pyroxene and lime-soda feldspar, but it may contain hornblende and resemble diorite, or have ophitic structure and pass into diabase, or be compact like basalt. Much of the greenstone, too, is locally vesicular and this feature, occurring in rock associated with beds of fragmental volcanic material, shows clearly that a large part of the fine-grained greenstone is of volcanic origin, and its relation to the fossiliferous limestones noted above indicates that the volcanoes from which it came were active, some in the Paleozoic era and others in the Mesozoic. These volcanic greenstones of various ages have been cut by numerous dikes and irregular masses of intrusive rocks of the same kind, and the whole has been so crushed and veined by later earth movements in the process of mountain building that it would be very difficult to map these rocks in detail separately.

A few irregular masses of serpentine cut the older greenstones. For the most part they have resulted from the alteration of peridotite or pyroxenite, but some may have come from a basic phase of the greenstone.

Granodiorite similar to that which covers a large area in the vicinity of Grants Pass forms irregular masses and dikes at a number of places. It is composed chiefly of plagioclase feldspar, quartz, and hornblende, generally with more or less mica and orthoclase feldspar, and with the increase of hornblende it varies in color from fine gray to greenish black.

The dacite porphyry is a light-colored rock which in composition and origin is closely related to the granodiorite. It forms dikes, and, though widely distributed, is not abundant. Some of it is decidedly porphyritic, with phenocrysts of feldspar and quartz.

The augite andesite is a dark-colored rock that occurs in a few small dikes cutting all the other igneous rocks as well as all the sedimentary rocks up to the top of the Horsetown.

The relative age of the igneous rocks, aside from the Paleozoic and Mesozoic greenstone lavas, is fairly well established. The greenstones are the oldest, followed in order by the serpentines (peridotites), granodiorite. dacite porphyry, and augite andesite. Although some of the greenstone lavas, and perhaps, also, some of the intrusive greenstones, are Paleozoic, the bulk of the intrusive rocks, including greenstones, granodiorite, peridotite, and dacite porphyry, belong about the close of the Jurassic. The augite andesite is the only igneous rock in the region under consideration that cuts the Cretaceous sediments.

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STRUCTURE.

The strike of the strata older than the Cretaceous is generally northeast and southwest, parallel to the rock belts, and their dip for the most part is to the southeast, though in many places they are vertical. To judge from the position of the strata alone it appears that those in the northwest portion of the Grants Pass region should be the oldest, and that they should decrease in age to the southeast. Just the reverse, however, is the case. The youngest rocks (Jurassic) are on the northwest, and the oldest (mica schist) on the southeast, with the Paleozoic between. This apparent reversal of the natural order is due either to folding and overturning of the strata or to faulting, by which the older rocks are made actually or apparently to overlie the younger. It is very probable that both folding and faulting have contributed to the complex structure of the region, but the part played by each is practically unknown and can be determined only by detailed investigation.

The most probable line of faulting noted in the region is one which crosses it from northeast to southwest in the vicinity of Waldo and Kerby, where the Jurassic strata appear to pass beneath the Devonian. A similar line of displacement may occur in the southeastern portion of the Applegate region, between the Paleozoic rocks and the mica schists; but the evidence thus far observed is not conclusive. Both of these supposed lines of faulting have been traced by Hershey southward through the Klamath Mountains, and are shown on the geomorphic map of the California earthquake commission.

METALLIFEROUS MINERAL RESOURCES.

By G. F. Kay.

INTRODUCTION.

The mineral resources of the area under consideration are chiefly gold and copper, the former occurring in gold-quartz veins and in placer deposits. Small amounts of silver are associated with the gold, and from the placers some platinum is obtained. Stibnite, josephinite, and cinnabar have been found, but not in sufficient quantities to be profitably worked. The region in which these minerals occur lies within Jackson and Josephine counties, and covers considerably less than half of their area. The mineral production of these two counties in 1907 had a value of $443,370. Of this amount about 75 per cent came from the mines of the area here described. For that year the value of the production of the copper mines was greater than that of the gold-quartz mines but less than that of the placers.

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GOLD-QUARTZ MINES.

GENERAL DESCRIPTION.

The most productive gold-quartz mines which were in operation in this area during the summer of 1908 were the Braden and the Opp.[a] The Granite Hill and Mountain Lion mines, although not now being worked, have also been fairly important producers within the last few years. There are many mines and prospects on which work is not now being done, some of which have never produced, some of which have produced values of a few hundred dollars, and a few of which have produced values of several thousand dollars. At present some development is in progress on new prospects and on mines which were until recently closed. The total gold production of the gold-quartz mines of the area in 1907 was about $70,000.

The gold-bearing quartz is widely distributed and occurs in small veins, veinlets, and brecciated zones, in several kinds of rock. Most of the mines and prospects are in the greenstones, but some are in the granodiorites, some in metamorphosed sediments, and a few prospects in peridotites or their decomposition product, serpentine. The ores are found in several relationships in these rocks. In some places they occur in greenstones at considerable distances from other kinds of rock; in others, they are in the greenstones but at the contact with or near to granodiorites and related rocks. Some veins are parallel to the schistosity in the greenstones. Again, some veinlets are in both greenstones and sediments, and in such occurrences, it is not unusual to find rich ores near the contact of these rocks and closely related to dikes which cut them. This relationship of the rich ore to dikes is also shown where the veinlets are in sediments only. In the peridotites some of the veinlets are at the contact with or near to dikes related to granodiorites.

Many of the veins and veinlets have never produced important bodies of ore but only "pockets," some of which, although filling but small spaces, were remarkably rich, the gold usually having been coarse. In general, the main part of the gold in these pockets has been taken from depths less than 25 feet from the surface.

The veins and veinlets run in all directions. However, a comparison of the more persistent of them showed that more lie in an east-west direction than in a north-south direction. The dips of the veins vary greatly; most of them have fairly high dips, but some are nearly flat and some are vertical. The widths of the veins are usually less than 1 foot; a great many are considerably less, and in some places they form an intricate network of stringers. On the other hand, there are veins with widths of more than 10 feet; in such veins

[a] The Opp mine was not examined.

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either " horses " are present, separating the vein into several parts, or there is a decided brecciation of the materials.

The vein filling consists mainly of quartz, which is usually of a milky-white color. In many of the veins the quartz has crystals with perfect outlines, indicating that the deposition took place in open fissures. Calcite is frequently found with the quartz, and subordinate amounts of sulphides, chiefly iron pyrites, but not uncommonly arsenopyrite, chalcopyrite, and galena are also present. A few of the veins contain pyrrhotite. The sulphides rarely exceed 3 per cent of the ores. At the Jewett mine, near Grants Pass, and the Homestake prospect, on Lightning Gulch, a branch of Canyon Creek, gold tellurides occur.

A study of the fillings of the veins in different kinds of rock suggests that the nature of the country rock has not, to any appreciable extent, influenced the contents of the fissures. The gold is present as free gold in the quartz and also associated with the sulphides and tellurides, the concentrates at times being rich.

Few values have been found in the country rocks adjacent to the veins. These rocks are in some places only slightly altered, but in other places they have been chloritized and in still others the products of alteration consist of carbonates, albite, quartz, and pyrite. The presence of albite rather than sericite, a mineral frequently found in the wall rocks of the gold-quartz mines of California,[a] is, no doubt, due to the fact that the Oregon rocks, as indicated from the analyses thus far made, are considerably richer in sodium than in potassium.

The lower limit of the zone of oxidation is in general less than 100 feet below the surface, but in places it exceeds 200 feet.

The evidence suggests that the gold-bearing veins are younger than the early Cretaceous and older than the Eocene, but some of the veins associated with the Paleozoic rocks may be pre-Cretaceous.

DESCRIPTIONS OF THE CHIEF MINES AND PROSPECTS.

BRADEN MINE.

The Braden mine is in the SE. ¼ sec. 27, T. 36 S., R. 3 W., about 3 miles from Gold Hill. It is now owned by C. R. Ray, of Tolo, but during the past year it has been leased to the Opp Mining Company, of Jacksonville. I am indebted to E. W. Liljegran, mines manager for Mr. Ray, for information with regard to this property.

This mine was located about twenty-five years ago by B. A. Knott, of Gold Hill. He began development, the ores being treated in an arrastre. The ownership of the mine passed in succession to several persons, one of them being Dr. James Braden, after whom the mine is named. He sold to Mr. Ray in 1900. The greatest production

[a] Lindgren, Waldemar, Trans. Am. Inst. Min. Eng., vol. 30, 1901, p. 665.

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of this mine for any one year was in 1907, when the value of the output was more than $30,000.

The equipment of the mine consists of a 10-stamp mill, one giant crusher, four Johnston concentrating tables, one air compressor, and machine drills. The plant is equipped with an electric power system, the power being brought from Tolo, on Rogue River, a distance of about 5 miles. The property has been developed mainly by drifts along the vein and by winzes and upraises from these drifts. The vein outcrops along the southeastern slope of a hill and dips southeastward. The angle of dip of the vein is greater than the angle of slope of the hill; hence the lower drifts on the vein are at greater depths below the surface than those higher up on the vein. There are four main drifts, one above another. The aggregate length of these drifts is nearly 3,000 feet, and the greatest depth below the surface—less than 250 feet—is in a winze from the lowest of these drifts. The longest drift is the lowest on the vein. It has a length of more than 1,200 feet, and considerable high-grade ore has been taken from the winzes and upraises made from it.

The rocks in which the ores are found are fine grained and of a dark-gray color; in hand specimens small crystals of feldspar may be seen. Under the microscope the rock appears distinctly porphyritic, the groundmass being microcrystalline. The phenocrysts are mainly plagioclase feldspar, but a few crystals of hornblende, probably secondary from augite, are also present. This rock is related to the greenstones, a large area of which lies in a northeast-southwest direction in this part of Jackson County. The area widens rapidly toward the south. The main part of this large area of greenstone is thought to be volcanic rocks interbedded with Paleozoic sediments. The evidence in favor of these rocks being volcanic consists of the presence, in many places, of amygdaloidal and tuff-like characters. Where such characters are absent it is difficult to distinguish those greenstones which are of volcanic origin from those which are fine-grained intrusives.

The vein in which the ores are found strikes about N. 30° E. The average width of the vein is not more than 2 feet; in places it pinches entirely; in other places, instead of one distinct vein with definite walls, there is a brecciated zone, which varies from a few feet to more than 15 feet in width. Within this zone the aggregate width of the quartz veinlets does not exceed 3 feet. In general, the dip of the vein is about 25° SE., but in some places it is nearly flat and in others the angle of dip is high. There are several faults, but they are of small throw—usually from 1 foot to 3 feet, rarely as much as 20 feet. These faults are approximately parallel to one another.

The vein filling consists chiefly of quartz and sulphides; a very subordinate amount of calcite is present. The most abundant sul-

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phide is pyrite, but arsenopyrite, chalcopyrite, and galena occur in small quantities. The best values are found in those parts of the vein which are richest in sulphides; where the quartz is comparatively free from sulphides, the gold content is low.

During 1907 the average yield of concentrates was 1 ton from every 12.2 tons of crude ore; these concentrates had an average value of $26 a ton. The average gold and silver content of more than 3,700 tons of ore treated in 1907 was worth about $9 a ton; the silver content was worth only about 22 cents a ton. About 65 per cent of the values of the ores was saved by amalgamation and about 25 per cent by concentration; the remaining values were lost in the tailings. The concentrates were shipped to Selby and to Tacoma.

The main part of the production of the mine has come from two shoots, which are nearly 600 feet apart on the lowest drift of the mine. One of the shoots extended along the vein in this drift for about 55 feet, but in a winze its width increased to about 80 feet, below which it narrowed rapidly. The direction of the shoot was the same as that of the dip of the vein. The other shoot had a length along the strike of the vein of 75 feet; in a winze from it the length increased to 125 feet; at the bottom of the winze, which was run 200 feet below the drift, the values were low. The direction of this shoot was about S. 50° E. Usually the best values were found along the foot wall of this shoot, although in places the values were uniformly distributed across the vein, which here had an average width of about 18 inches.

The zone of oxidation does not extend to a depth greater than about 100 feet below the surface, and in parts of the vein sulphide ores are found at depths considerably less. Along the fault planes the ores show enrichment.

GRANITE HILL MINE.

The Granite Hill mine is in sec. 29, T. 35 S., R. 5 W., near the north boundary of the Grants Pass quadrangle. A good wagon road runs from Grants Pass to the mine, a distance of about 9 miles. At the time of my visit (July, 1908) this mine had been closed for several months and all the workings were filled with water. From Mr. C. M. Morphy, the former superintendent, many of the following facts were obtained. The mine is now owned by the American Goldfields Company, which also owns the property in the vicinity, including the Red Jacket and Ida mines, on which several hundred feet of development work has been done. The present owners obtained the Granite Hill property in 1901, and almost all the development work has been done since that time. During the years 1904 to 1907 the value of the production was more than $65,000. the largest output having been in 1905.

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The mine is equipped with a 20-stamp mill, which has a capacity of 100 tons a day; a crusher, concentrating tables, engines, compressors, hoists, machine drills, and a Worthington mine pump. Electric power was used. When the mine was in operation as many as 50 men were employed.

The mine was developed by workings which aggregate nearly 3,000 feet. A vertical shaft of 420 feet intersects the vein at a depth of about 120 feet. From depths of 200, 300, and 400 feet on the shaft crosscuts were run to the vein and drifts made along the vein. The profitable ore between the levels was stoped out and raised through the shaft to the surface.

The country rocks are related to the granodiorites, a narrow tongue of which extends southward into the Grants Pass quadrangle from a larger area of these rocks in the Riddles quadrangle. To the east of the granodiorites is greenstone; to the west, serpentine. At the Granite Hill mine the values have been found only in the granodiorite, but at the Red Jacket and Ida mines they occur in the greenstone.

The vein runs in an east-west direction and has an average width of about 5 feet. In places the vein is brecciated, the fractured zone having a maximum width of about 20 feet. The dip of the vein is about 70° S. The vein filling consists of quartz, pyrite, chalcopyrite, and galena, carrying gold. The sulphides comprise about one-half of 1 per cent of the ores, and as concentrates they yield about $75 to the ton. The average gold value of all the ores treated in 1907 was about $5 a ton.

Mr. Morphy stated that the richest ores were found in shoots, of which there were three, each having a length along the vein of about 150 feet and a direction of dip to the west of south.

The zone of oxidation extends to a depth of more than 200 feet from the surface, and from the oxidized ores the best values were obtained.

MOUNTAIN LION MINE.

The Mountain Lion mine is in the western part of sec. 1, T. 38 S., R. 5 W. It was discovered in 1889 by the Messrs. Bailey, who, with Messrs. Davidson, Jewell, and Harmon, are the present owners. No work has been done on the property for several months. The equipment consists of a 5-stamp mill, with concentrating tables, compressor, and engines. When the mine was in operation, as many as 25 men were employed.

The property has been extensively developed, there being about 8,000 feet of crosscuts, drifts, and other workings. Work has been done on two veins, which are in greenstone and slates and which are close to the contact of these rocks, with an area of granodiorite. The

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APPALACHIAN ST

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JEWETT MINE.

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quartz is a small amount of pyrite, pyrrhotite,
eel-gray mineral, which when boiled with con-
acid gives the purplish-colored reaction char-
ide. The properties of the mineral correspond to
It was found without difficulty in several tons of

HOMESTAKE PROSPECT.

prospect is on the main branch of Lightning Gulch,
on Creek, which flows into Josephine Creek about
unction with Illinois River. It was formerly owned

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slates occur as narrow lenses in the greenstones, and the best values of the veins have been obtained near the contacts of the greenstones and the slates. The better-defined vein of the two has a direction of N. 80° W. and dips 65° S. It averages about 1 foot in width and is faulted at many places. The vein filling consists chiefly of quartz, calcite, and sulphides, the sulphides constituting about 1 per cent of the whole. Owing to the prevalence of faults the vein has been difficult to follow.

TIN PAN MINE.

The Tin Pan mine is in the SE. ¼ sec. 31, T. 36 S., R. 3 W., on the divide between Galls Creek and Foots Creek. The property was located many years ago. It is now owned by the Pacific American Gold-Mining Company. T. T. Barnard was superintendent during the summer of 1908.

The mine is equipped with a 10-stamp mill, a Blake crusher, and two concentrating tables. No large body of profitable ore has been found, although more than 1,200 feet of drifts, shafts, and other workings have been made on the vein.

The country rocks in which the ores occur are slates, limestones, and greenstones, the greenstones apparently being intrusive in the sedimentary rocks, although some of them may be volcanic. The direction of strike of the sediments is about N. 13° E. The strike of the vein is between northeast and east, and the dip is nearly vertical. The width of the vein varies from less than 18 inches to more than 6 feet of solid quartz between definite walls, which are usually but slightly altered. In places there is a gouge from 1 to 3 inches in width. This material is clay like, but it contains carbonates and sulphides. The chief values of the vein are in the sulphides, which run about $60 to the ton. The sulphides are pyrite and galena, which together constitute less than 2 per cent of the ores. Some faulting has occurred.

The zone of oxidation reaches a depth of more than 100 feet.

STAR MINE.

The Star mine is in sec. 6, T. 39 S., R. 4 W., west of Thompson Creek and about 4 miles from Applegate post-office. This property was located in 1896 by J. J. Kunutzen. Very little development work was done until 1904, when E. B. Hawkins and Harry N. Morse became the owners. They spent about $20,000 in development. Thus far only about 800 tons of ore has been milled. The gold content was low, running only from $2 to $4 a ton.

The ore was quarried from an area of fine-grained greenstone in which there were numerous small stringers of gold quartz running in various directions. No distinct vein was found.

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MAID OF THE MIST MINE.

The Maid of the Mist mine is in sec. 4, T. 39 S., R. 4 W. It is owned by William Wright, who did considerable work on the property during 1906, but suspended operations in May, 1907. During the summer of 1908 it was bonded by the South Oregon Mines Company, and preparations were being made to conduct extensive developments. More than 500 feet of work, mainly in shafts and drifts, had already been done, and compressors and hoists were being installed.

The country rock is greenstone. The gold-bearing quartz occurs in veinlets, which run in various directions. One of the most persistent of these runs N. 85° W. and dips 55° S. The values are irregularly distributed through the quartz, which is fairly free from sulphides. Of the sulphides, arsenopyrite appears to be more prevalent than pyrite. Calcite is subordinate.

JEWETT MINE.

The Jewett mine is close to the boundary between secs. 27 and 34, T. 36 S., R. 5 W., about 4 miles from Grants Pass. It was discovered about 1880 by Thomas Jewett. It now belongs to the estate of Benjamin Healy, of San Francisco. During the summer of 1908 no work was being done, but J. T. Hoare, the superintendent, stated that development was soon to be resumed. A short distance from the mine is a 5-stamp mill. There are seven claims, on which more than 1,500 feet of work has been done.

The country rocks are intrusive greenstones closely related to gabbro. Near the workings a dike of granodiorite cutting the gabbro was observed. The ores do not occur in a vein with definite walls, but in small stringers in a brecciated zone, which is irregular both in direction and in width. The most pronounced direction is about N. 20° W. In places the width of the zone of brecciation is more than 20 feet. The filling between the fragments of the breccia consists chiefly of quartz and calcite, the latter being subordinate. Irregularly distributed through the quartz is a small amount of pyrite, pyrrhotite, and a glistening steel-gray mineral, which when boiled with concentrated sulphuric acid gives the purplish-colored reaction characteristic of a telluride. The properties of the mineral correspond to those of sylvanite. It was found without difficulty in several tons of ore on the dump.

HOMESTAKE PROSPECT.

The Homestake prospect is on the main branch of Lightning Gulch, a tributary of Canyon Creek, which flows into Josephine Creek about 4 miles above its junction with Illinois River. It was formerly owned

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by the Lewis and Clark Gold Mining Company, but is now owned by the Homestake Mining Company, of which E. A. McPherson, of Kerby, is manager.

The chief development on this property is a tunnel about 180 feet long. The country rock is a somewhat siliceous greenstone, which is in places decidedly schistose. Veinlets parallel to the schistosity contain quartz and calcite, with which are associated native gold, gold telluride, and iron pyrites. The values are irregularly distributed, some of the ores being rich. The strike of the schistosity is north and south; the dip is 65° E.

OTHER MINES AND PROSPECTS.

Not far from the Homestake are other prospects from which gold tellurides are reported. Of these the Booth prospect, on the west fork of Lightning Gulch, and the Challin & Finch prospect about 1½ miles from the head of Canyon Creek, are the most important.

There are several other mines and prospects which might be described, but they would present no new features. Among such may be mentioned the Michigan mine, Bill Nye mine, Lawrence mine, McMurtry mine, Alice group, Gold Pick mine, Gardner prospect, Pratt prospect, Millionaire mine, Oregon Bonanza mine, Oregon Belle mine, Gray Eagle prospect, and Owl Hollow prospect. On the first seven of these no work has been done for some time; on each of the others a small amount of development is being done. Chief among the "pockets" of ore that have been found within the area are the Gold Hill, the Roaring Gimlet, the Revenue, the Steamboat, and the Harrison. The locations of these are shown on the map.

CONCLUSIONS.

The gold-quartz veins and veinlets of this area are in all important features similar to those of the Riddles quadrangle, which were described in Bulletin 340 of the Survey. Of the many veins and veinlets on which work has been done few have developed into profitable mines, and the outlook for profitable gold-quartz mining in the region is not encouraging. This unpromising condition is due to the structural features of the rocks of the area. These rocks, previous to the mineralization, had been so fractured and fissured by earth movements that later, when precipitation took place from the gold-bearing solutions passing through the rocks, the gold was widely disseminated and not concentrated into definite lodes such as are favorable to gold-quartz mining. Moreover, the difficulties of mining have been increased by faulting subsequent to the formation of the veins. To the widespread distribution of the values, however, is due the fact that placer gold is found in so many of the streams of this part

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of the country. The veins and veinlets carrying the gold have been undergoing erosion for many thousands of years, and during this time the gold has been carried by water and by gravity into the stream beds, from which it has been and is being mined.

PLACER MINES.

GENERAL OUTLINE.

The placer mines of Jackson and Josephine counties produced in 1907 gold to the value of $229,575, of which $107,722 came from Jackson County and $121,853 from Josephine County. More than 75 per cent of the production of Jackson County and more than 30 per cent of that of Josephine County came from the area described in this report. The chief districts contributing to this production are the Gold Hill, the Foots Creek, the Applegate, and the Jacksonville districts, in Jackson County; and the Althouse and Sucker Creek, the Williams Creek, the Waldo, and the Kerby districts, in Josephine County.

The gravel deposits that are being mined in these districts vary in thickness from a few feet to more than 50 feet. The average thickness of the gravels of all the important mines is more than 20 feet. The material of the deposits ranges from fine clay with but few bowlders to gravels that contain bowlders weighing several tons. The bowlders are, as a rule, fairly well rounded where the gradients of the streams are steep, but where the gradients are flatter, they are subangular and even angular. The predominating bowlders in the gravels are greenstone, but the kinds of bowlders vary in the different stream beds in accordance with the various kinds of rock in which the valleys have been cut. In many of the deposits the coarsest material is at or near the bed rock, but in some the bowlders are somewhat uniformly distributed throughout the section of the gravels.

With but one exception the placers are in gravels closely associated with the present streams, the deposits being either in the present stream beds or on terraces not many feet above them. The exception is at the High Gravel or Allen Gulch mine, near Waldo. Here the gravels are of Cretaceous age and lie on the divide between the east and west forks of Illinois River.

The gold content of the gravels varies greatly. In some of the best mines the average value is from 20 to 40 cents a cubic yard. The best values have usually been found at or near the base of the deposit. Much of the gold is fine, but nuggets are frequently found.

Many of the placer deposits have a bed rock of greenstone, which is in places considerably decomposed, fractured, and fissured, many of the fissures being filled with veinlets of quartz. But the gravels containing the gold are by no means confined to areas of greenstone.

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Some of the placers have a bed rock of granodiorite, some of serpentine, and some of slate. In the Waldo district gravels are being mined which lie on Cretaceous conglomerates and sandstones. Much of the material of the deposits has been transported for considerable distances, and hence its origin bears no immediate relation to the rock on which it now lies. As the greenstones are the most widespread rocks of the region and as from them much of the gold of the quartz mines has come, it is reasonable to conclude that much of the placer gold has come from the veins and veinlets of the greenstone areas. But inasmuch as gold-bearing quartz is found also in other kinds of rock in this region, these have, no doubt, contributed gold to the placers. The usual slope of the bed rock is about 150 feet to the mile.

Placer mining is carried on chiefly during the first half of the year, when the supply of water is most abundant. A few mines are so equipped that there is sufficient water to operate them for a greater part of the year. Only one mine, the Champlin, on Foots Creek, is equipped for dredging; the other important mines are equipped for hydraulicking. The ground-sluicing method is used only in the small mines.

In many of the mines from three to five men are employed, but as many as fifteen are employed in some of the larger mines during the mining season.

GOLD HILL DISTRICT.

In the Gold Hill district there are no large placer mines. The most important is the Blockert mine, on Galls Creek. On the same stream work is being done on a few other properties. The gravels worked are in the present stream bed. The hydraulic method is used. On Sardine Creek also some mining is being done.

It is of interest to note that during the summer of 1908 preparations were being made to mine, by electric dredge, deposits to the south of Kane Creek, in the SW. ¼ sec. 36, T. 36 S., R. 3 W. The Electric Gold Dredging Company, of which H. A. Mansfield, of Indianapolis, is manager, had already begun work. The electric power shovel to be used is equipped with three motors, one for hoisting the dipper, one for swinging the crane or boom, and one on the crane or boom for crowding the dipper into the bank. The capacity of the shovel is about 500 cubic yards in ten hours. The electric power is brought from the Ray dam on Rogue River, 2 miles away. The water to be used in washing the gravels is obtained from reservoirs on the small stream which flows through the property. The material of the deposit is fine-grained clay and gravel having an average thickness of about 18 feet; very few bowlders are present. The bed rock is slate with a strike of N. 55° E. and a dip of about 70° SE. The slates have been considerably altered.

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FOOTS CREEK DISTRICT.

There are several placer mines on Foots Creek. Of these, the chief producer is the Champlin mine, located on the creek just below the forks. The other mines are the Black Gold Channel and Cook, on the Left Fork, and the Lance and Glen Ditch on the Right Fork. For the notes on the mines on the forks I am indebted to Mr. Diller.

CHAMPLIN MINE.

The Champlin mine is on Foots Creek, about 2 miles from its junction with Rogue River. It is owned by the Champlin Dredging Company, of Chicago, which bought the property in 1903 from Mr. Lance, of Gold Hill. In the same year the company constructed a bucket dredge equipped with steam power. In November, 1905, electric power was installed, the cost of mining being thereby reduced about one-half. Thirty-six buckets are used, each of which holds 8 cubic feet of material.

The average depth of the pay gravel is about 35 feet, but deposits to depths of 46 feet have been mined without reaching bed rock. Much of the material is less than 5 inches in diameter, but bowlders of large size are numerous. The best values are found in a bluish gravel, which is generally reached at a depth of about 12 feet. This gravel is from 8 to 18 feet in thickness. Below it is a fine plastic clay, which is difficult to handle, and which carries practically no gold. In the present workings this clay is not being mined. The property contains more than 1,200 acres of placer ground, much of which has been thoroughly prospected and found to carry gold.

BLACK GOLD CHANNEL MINE.

The Black Gold Channel mine is on the Left Fork of Foots Creek, in sec. 12, T. 37 S., R. 4 W. It is leased at the present time. In the bank is exposed about 15 feet of unstratified gravels, coarsest below, and containing bowlders up to 18 inches in diameter. There is very little fine material; the bowlders, which are almost all of greenstone, are subangular to fairly well rounded. The large bowlders are handled by a derrick. Two giants are used under a head of several hundred feet. The gravels are forced upward for 15 feet over an elevator, but the sluice takes the material 2½ feet above bed rock. The mine pit of the present workings has an area of 1½ acres. A large area down the stream has already been worked over. The bed rock is slate cut by dikes of greenstone. The strike of the slates is N. 10° E.; distinct joints run about N. 70° W. Numerous small veins are present, and have a general northeast-southwest direction.

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COOK MINE.

The Cook mine is in the S. ½ sec. 13, T. 37 S., R. 4 W. The pay gravel is, in places, plainly stratified, and consists mainly of fine gravel and clay. The stream bed has been mined for one-fourth of a mile. The bed rock is made up of greenstone and slates cut by numerous greenstone dikes. It has been greatly sheared and faulted. One fault runs N. 75° W. and dips 31° N.; another runs N. 53° E. and has been traced for nearly one-fourth of a mile.

LANCE MINE.

The Lance mine is on the Right Fork of Foots Creek, in the SE. ¼ sec. 22, T. 37 S., R. 4 W. It is owned by the Lance Brothers, but is leased at present. The bank has in places a thickness of 20 feet; much of the material is fine. The bed rock consists of lenses of limestone in slates, which are cut by dikes of greenstone. The bed of the stream has been mined for about one-third of a mile, and there is still considerable good ground to be mined.

GLEN DITCH AND OTHER MINES.

The Glen Ditch mine is near the head of the Right Fork of Foots Creek. It is owned by Boling Brothers. The stream bed has been followed for some distance, but much good ground remains to be worked. The gravels are about 15 feet thick.

Other small producers on the Right Fork are the Mattis and Hausman mines.

APPLEGATE DISTRICT.

The chief mines of the Applegate district are located on small streams flowing into Applegate River. The most important are the Layton mine, on Ferris Gulch; the Johnston and the Benson mines, on Humbug Creek; and the Brantner mine, near the mouth of Keeler Creek.

LAYTON MINE.

The Layton mine is part of the estate of J. F. Layton. The average thickness of the gravels is about 25 feet and the width, from rim to rim of the pay channel, is more than 200 feet. In much of the material the pebbles are less than 6 inches in diameter and are usually subangular. The largest bowlders are in the bottom of the deposit and in places they are considerably decomposed. The best values are found in an old channel about 15 feet below the level of the present stream bed. In this channel the fall is about 4 feet in 100 feet. The gold is usually in small flakes, but nuggets are also found. The bed rock is greenstone, which in places is distinctly vesicular

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and greatly fractured and veined. Some of the veinlets are as much as 4 inches in width. Narrow bands of slaty rock are interbedded with the volcanic rocks, which have a strike of about N. 40° E. and dip to the southeast.

Mining is carried on each year from February until September. The early miners had a small ditch with a head of 100 feet, but Mr. Layton put in two ditches, the upper of which is 21 miles long and the lower 18 miles. The water of both ditches comes from Williams Creek. Two giants are used under a head of about 300 feet. Five men are generally employed, and the amount mined off each year is somewhat more than 1 acre. The property was secured by the present owners in 1877 and since that date mining has been carried on each year. A considerable area of good ground remains to be washed.

JOHNSTON MINE.

The Johnston mine is in sec. 11, T. 38 S., R. 4 W., at the junction of the west branch with the main Humbug Creek. The present owner is W. H. Johnston. The bank averages about 8 feet in thickness and contains considerable clay, in which the main values are found. Bowlders of greenstone and granodiorite, from 6 inches to more than 8 feet in diameter, are present. Much of the mining has been confined to the bed of the stream. The bed rock consists of fine-grained greenstone, much fractured and veined. The mine is equipped for hydraulicking, the waters being brought from Humbug Creek. The supply of water is so scanty that, in general, the mine can not be operated for more than three months each year. Mining has been done on this stream for more than thirty years, during which time more than 30 acres has been mined.

BENSON MINE.

The Benson mine is on Humbug Creek in sec. 14, T. 38 S., R. 4 W. It is owned by S. L. Benson. The property consists of about 1 mile of the stream bed. The gravels are about 20 feet in thickness and contain many large angular and subangular bowlders, which are rather uniformly distributed throughout the section of the deposit. The gold is found mainly in the bottom. The bed rock is greenstone. This mine has been in operation for many years, but was not equipped for hydraulicking until the spring of 1908.

BRANTNER MINE.

The Brantner mine is on Applegate River, near the mouth of Keeler Creek. It is owned by D. H. Mansfield. In the present workings the sands and gravels have a thickness of 30 to 35 feet and show

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distinct stratification. Many large angular and subangular bowlders are found at and near the base of the deposit. All the material above this is fairly well rounded and contains few bowlders. The bowlders are chiefly of greenstone and are comparatively unaltered. The surface of the terrace now being worked is about 40 feet above Applegate River. The bed rock is decomposed greenstone. The mine is equipped for hydraulicking, the water used having a pressure of about 100 feet. The large bowlders are handled by derrick. There is sufficient water to operate the mine for about three months of each year. Altogether, more than 20 acres have been mined, and considerable good ground remains to be washed.

JACKSONVILLE DISTRICT.

In the Jacksonville district is the Sterling mine, the most productive placer mine of southwestern Oregon; also the Old Sturgis, the Spaulding, and the Pearce.

STERLING MINE.

The Sterling mine is on Sterling Creek, a branch of Little Applegate River, and is about 8 miles from Jacksonville. It is owned by the Sterling Mining Company, of which J. D. Heard is manager. The property includes about 2,000 acres, extending from a point below the mouth of Sterling Creek to the head of Sterling Creek and over the divide to Griffin Creek. The gravel bank on the west side of the present workings is more than 40 feet in thickness, but on the east side it is only about 20 feet thick. The section consists of gravel and bowlders, the latter being rather uniformly distributed throughout the section. Many of the bowlders are small, but some are more than 2 feet in diameter and a few exceed 8 feet. They are mainly of greenstone.

Much mining has been done on Sterling Creek by the present company. The main stream was mined up from its mouth for more than 3 miles, then a channel to the east of this stream was followed for about half a mile. Here a channel, which is named Bowlder Channel, was struck, and this has been followed for about a quarter of a mile to the present workings. The bed rock of these workings is a little higher than the present stream bed and is about 100 yards east of it. The values are found across a width of nearly 200 feet. The gold is of medium coarseness and is usually well rounded, although angular nuggets are also present. The average thickness of the gravels in the Bowlder Channel is about 40 feet. It is of interest to note that in these gravels the tusks and jaws of a mammoth, as well as other mammalian bones, have been found. The bed rock at the mine is greenstone, in which are patches of slaty tuffs. These rocks have been con-

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siderably sheared and veinlets of quartz are present. The strike of the slaty rocks is N. 8° E., the dip about 60° W. In the present workings is a dike running N. 20° E., containing cross veins which do not extend beyond the dike. The slope of the bed rock is about 2 feet in 100 feet. In 1908 mining was in progress from March until August, during which time about 1 acre was mined. The value of the gravels was about 40 cents to the cubic yard.

The mine is well equipped with ditches, giants, and flumes. The longest ditch is about 27 miles in length. The water enters the ditch from Little Applegate River about 12 miles above the mouth of Sterling Creek. At the mine the head of the water is now only about 80 feet. A pipe line is being planned to carry water from Squaw Lake to the mine, a distance of 17 miles. The mine has been equipped for hydraulicking for about thirty years. The Sterling Mining Company was incorporated in 1872. There were issued only 40 shares of stock, which have been held by a very few shareholders. The total production of the mine is said to exceed $3,000,000.

SPAULDING MINE.

The Spaulding mine is on Forest Creek in sec. 4, T. 38 S., R. 3 W. The maximum thickness of the deposit in the present workings is more than 40 feet, but the average thickness does not exceed 25 feet. The lowest 10 feet consists of gravels containing bowlders; the upper part of the deposit is hardpan. Even in the lower part there are but few bowlders, and these are usually less than 1 foot in diameter. They are rounded or subangular and are usually of greenstone, although some are of granodiorite. The mine is equipped for hydraulicking.

OLD STURGIS MINE.

The Old Sturgis mine is on Forest Creek in sec. 10, T. 38 S., R. 3 W. It is now owned by the Sterling Mining Company. G. L. Jones is the foreman. The deposit has an average thickness of about 30 feet; the maximum thickness is about 60 feet. In the lowest 10 feet are gravels and sand containing rounded and subangular bowlders, which are chiefly of greenstone, although some are of granodiorite. The upper part of the deposit is hardpan, which has a reddish to buff color. The gold is fine, and the best values are near the bottom. The richest ground is said to run as high as $12,000 to the acre. The bed rock is greenstone much fractured and veined; in places it is very slaty, the strike being N. 30° E. and the dip 48° SE. In the mine pit the bed rock is about 8 feet above the stream bed and the slope is very gentle. The water supply is such that the mine may be operated from one to four months each year. The

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main ditch is about 1½ miles in length. The mine is equipped with giants, and a derrick is used for handling the bowlders. About 1 acre a year is mined. From 8 to 12 men are employed. The property contains about 900 acres, a large part of which is placer ground. For many years the mine was owned by the Vance Mining Company.

PEARCE MINE.

The Pearce mine is on the east fork of Forest Creek in sec. 11, T. 38 S., R. 3 W. The gravels have an average thickness of about 12 feet, but in places they have been 45 feet thick. Where recent work has been done the bank is about 25 feet thick. In the lowest 6 feet of the deposit there are many large undecomposed bowlders, but above this zone the material is gravel and sand not very strongly cemented. The best values are at and near the bottom. In general the gold is rather fine. Some of the ground has run as high as $7,000 to the acre. The bed rock is greenstone, the slope of which is not more than 2 feet in 100 feet. The mine is equipped for hydraulicking, three giants being used. The pressure of the water is only about 85 feet. The water is brought 1½ miles from the upper part of the stream on which the mine is located. A derrick is used for handling the bowlders. The property consists of 240 acres, a large part of which remains to be worked.

In addition to the mines on Forest Creek already described, there are some other small producers. In the early days of placer mining in Oregon, Forest Creek was among the most productive streams.

ALTHOUSE AND SUCKER CREEKS DISTRICT.

From the gravels of Althouse and Sucker creeks a large amount of gold was washed in the early days of placer mining in Oregon, but for several years the production has not been great, as the best ground was worked many years ago. During 1907 the production of the streams of this district probably did not exceed $6,000. There are no large mines, but numerous small ones. Among these are the Jumbo, the Mountain Slide, the Slide, and the Yeager, on Sucker Creek and its branches. On Althouse Creek some work is being done on the Layman property, and recently the Klamath Development Company acquired eight claims near Grass Flat, on which considerable work is to be done. Some new ground was also being opened at the mouth of Portuguese Gulch, a small branch of Althouse Creek near its head.

WILLIAMS CREEK DISTRICT.

The chief placer mines in the Williams Creek district are the Horsehead mine, on a branch of Williams Creek, the Miller & Savage mine, on Miller Creek, and the Oscar placer, on Oscar Creek.

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HORSEHEAD MINE.

The Horsehead mine is in the SE. ¼ sec. 21, T. 38 S., R. 5 W., and is owned by Alexander Watt. The gravels vary in thickness from a few feet to 30 feet, with an average of about 18 feet. The deposit contains many angular and subangular bowlders considerably more than 1 foot in diameter. These are somewhat uniformly distributed throughout the section. Many of the bowlders are greenstone, but some are granodiorite. The finer materials are of a grayish to reddish color. The values are distributed through the gravels and as a rule the gold is fine. The bed rock is granodiorite, which has been fractured and crushed and in places has been disintegrated and decomposed to a depth of more than 10 feet. An area of more than 10 acres has been mined. The property is equipped for hydraulicking. The water is brought from Munger Creek, the ditch being 8 miles long.

MILLER & SAVAGE MINE.

Miller & Savage's mine is on Miller Creek in sec. 25, T. 37 S., R. 5 W. The gravels vary in thickness from 6 to 30 feet, with an average of about 18 feet. Many bowlders exceeding 1 foot in diameter are present, the largest of these being at the bottom of the deposit. The gold is mostly fine, but nuggets of large size have been found. The largest of these was found several years ago and is said to have weighed more than 13 ounces. The mine is equipped for hydraulicking. The present owners have mined each year since 1904, and considerable good ground remains to be washed.

OSCAR CREEK MINE.

The Oscar Creek mine is on Oscar Creek, a small stream which flows into Applegate River. The property comprises more than 300 acres. The gravels have an average thickness of about 12 feet and contain many rounded bowlders of medium size. The materials are not strongly cemented. The gold is found in flakes and in nuggets. The equipment consists of two giants, 1,100 feet of pipe, 300 feet of flume, and 3 miles of ditches. The supply of water is sufficient to carry on operations for about four months of the year. It is said that the property has produced more than $35,000.

WALDO DISTRICT.

In the Waldo district there are three important placer mines, the High Gravel or Allen Gulch mine, the Deep Gravel mine, and the Logan, Simmons & Cameron mine.

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HIGH GRAVEL MINE.

The High Gravel mine is about 1 mile south of Waldo on a ridge which forms the divide between the east and west forks of Illinois River. The summit of the ridge is about 1 mile from the east fork and is more than 300 feet above it. The chief workings are at the head of Allen Gulch, on the east slope of the ridge. The most recent workings, however, are on the west slope of the ridge. Of the summit of the ridge a width of only about 100 feet remains to be mined.

This mine is of unusual interest in that the deposits do not belong to the present stream bed or adjacent benches but are conglomerates which are, according to Mr. Diller, who has made a study of the geology of the region, of Cretaceous age.

The deposits mined on the west slope run parallel to the ridge. They are more than one-eighth of a mile in length and have an average width of about 100 feet. The conglomerates do not extend down the slope but constitute only a remnant which here has escaped erosion, as is true of other areas of conglomerate in the region. No conglomerate remains on the summit of the ridge a short distance to the north of the present mine pit. The surfaces on which the conglomerates were laid down were uneven, and hence the thicknesses of the conglomerates vary. The maximum thickness exposed is more than 60 feet. The conglomerates have a purplish tint. They are not strongly cemented and the bowlders are rather uniformly distributed throughout the section. Much of the material is less than 1 foot in diameter; a few bowlders are more than 3 feet. Distinct joints are present in the conglomerates, and a few small veinlets occur. The bed rock is a fractured, fissured, decomposed, and veined greenstone, which, owing to the presence of iron oxides, has a decidedly purplish tint.

The workings on the east side of the ridge extend down Allen Gulch to the east fork of Illinois River, but only those gravels which are near the summit of the ridge are of Cretaceous age. These conglomerates extend along the ridge in a north-south direction. At the south end of the workings they are more than 50 feet in thickness; at the north end and close to the summit of the ridge they are only a few feet thick, and a little farther on they have been completely eroded. The best values are said to be near the bed rock, but some gold is found higher up in the deposit.

These Cretaceous conglomerates are shore deposits, derived from older rocks, similar to those on which they now lie. As stringers carrying values are fairly widespread in these old rocks, some gold is probably present in much of the conglomerate which has been derived from them. But whether or not these values are sufficiently concen-

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trated, as at the High Gravel mine, to be profitably mined can be determined only by prospecting.

It is of interest to note that some placer mines in northern California are in conglomerates of Cretaceous age.[a]

DEEP GRAVEL MINE.

The Deep Gravel mine is about 1 mile northwest of Waldo. The property comprises about 560 acres in secs. 20, 21, and 28, T. 40 S., R. 8 W. It is owned by the Deep Gravel Mining Company. The main workings are in Butcher Gulch and its tributary gulches. The gravels of these gulches are included in a bench which extends from the head of Butcher Gulch to the west fork of Illinois River. The upper limit of the bench is about 1½ miles from the west fork and about 125 feet higher than the bed of this stream. The most recent workings are in Joe Smith Gulch, an eastern tributary of Butcher Gulch, where an area of more than 10 acres has been mined. At the upper end of these workings the gravels are about 12 feet in thickness; at the lower end they are more than 60 feet and the bank consists of gravel and sand containing practically no bowlders except in the lowest 10 feet, and even there few of them exceed 1 foot in diameter. Stratification is well shown. The bed rocks in Joe Smith Gulch consist of purplish conglomerates of Cretaceous age, similar to the conglomerates that are being mined at the High Gravel mine. As these conglomerates of the Deep Gravel mine have not yet been well prospected, their gold content is not known.

The mine pit of Joe Smith Gulch is 1,500 feet from the west fork of Illinois River. The elevation of the bed rock in the mine pit is more than 30 feet below the stream bed of the west fork, a fact that has greatly increased the difficulties of mining, necessitating the use of a hydraulic elevator. The elevator is situated at the lower end of a sluice with riffles. The pay gravel from the bank is first washed through the sluice, the coarse gold being caught on the riffles. Then the material including the fine gold is carried up 46 feet by the elevator, the water pressure used being about 200 feet. At the head of the elevator is a 4-foot flume, 400 feet in length, in which are wooden riffles placed about 1¼ inches apart and parallel to the length of the flume. A beveled steel strip is attached to the upper surface of each riffle. These steel strips are slightly wider than the riffles and, when they are set in place, are about three-fourths of an inch apart.

A clean-up is made about once a month. The gold is saved by amalgamation and is very fine. The concentrates are sold for their values in platinum, osmium, and iridium. Mr. Wimer, the presi-

[a] Eng. and Min. Jour., vol. 76, pp. 653–654.

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dent of the company, stated that the average value of the pay gravels during the last five years had been about 25 cents to the cubic yard.

The water used in the pit and in the elevator is brought by two ditches from the east fork of Illinois River. The longer of the two ditches is about 4 miles in length. There is on the property a race about 7,000 feet long that was used for many years when the gravels being mined were at an elevation greater than that of the outlet of the race. At present only the lower end is used.

The history of the Deep Gravel mine dates back for more than thirty years. The first owners were George and Walter Simmons. In 1878 Wimer & Sons bought a half interest and in 1888 they secured all rights to the property. In 1900 the Deep Gravel Mining Company became the owner. Mr. Wimer stated that about $130,000 has been expended on the property and that the output of the mine has been about $250,000.

LOGAN, SIMMONS & CAMERON MINE.

The Logan, Simmons & Cameron mine is northeast of Waldo, the present workings being in sec. 22, T. 40 S., R. 8 W. J. M. Logan is manager. The recent workings are on French Flat, where about 3 acres has been mined. Here the bank consists of gravel, sand, and clay, with a thickness varying from a few feet to 15 feet. Much of the material is fine; only a few bowlders are present, nearly all of which are less than 6 inches in diameter. The bed rock is purplish Cretaceous conglomerate, which has been fractured, fissured, and to some extent veined. The slope of the bed rock is very gentle.

An elevator which raises the material 38 feet is used. There are three ditches. The water from one of these has a pressure of 325 feet and is used in the elevator; that from another is used in two giants in the pit; and that from the third ditch is used in forcing the tailings from the end of the sluice at the head of the elevator. Mining is carried on for about eight months of the year.

The old workings on this property are in Carroll Slough, more than a mile north of the present pit on French Flat. The gravels have been mined in a north-south direction for more than a mile; the average width is about one-eighth mile, the average depth about 18 feet. The gold content was about 12½ cents to the cubic yard. The bed rock is made up in some places of serpentine and in others of Cretaceous conglomerates and sandstones.

This mine has been operated for about twenty-five years, but not until the last season was work begun on French Flat, where there is a considerable area of auriferous gravels. The present owners have operated the mine for the last eight years. Mr. Logan stated that during that time the value of the output has been about $50,000.

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KERBY DISTRICT.

The chief placer mine of the Kerby district is the Anderson & Wilson property on Illinois River about 6 miles from Kerby. Other producers are the Ray mine, which adjoins the Anderson & Wilson mine on the south, and, on Josephine Creek, the Flintlock mine, Morrison Brothers' mine, and the Josephine and Illinois Gold Mining Company's mine.

ANDERSON & WILSON MINE.

Anderson & Wilson's mine is on the east bank of Illinois River above the mouth of Deer Creek. The gravels are in benches adjacent to the river. The bed rock of the workings farthest down the stream is but little higher than the bed of the river. The gravels are about 20 feet thick and in places have been mined for a distance of about one-eighth mile back from the stream, where the slope rises steeply and the limit of the bench is reached. The sand and gravels are of a buff color and are well stratified. The largest bowlders are in the lowest 6 feet of the deposit.

The most recent work has been done on gravels lying south of those just described, about 50 feet above the level of Illinois River. The workings run parallel to the river for about 200 yards and extend back from it for about 150 yards. The gravels vary in thickness from a few feet to 25 feet. The upper part of the deposit is rather fine sand and gravel; below this there are many bowlders. Stratification is well shown.

The bed rock is serpentine. The water is brought from Fidler Gulch, a branch of Josephine Creek. It is conveyed across the Illinois at the mine in a large pipe.

OTHER MINES.

The Flintlock mine, Morrison Brothers' mine, and the Josephine and Illinois Gold Mining Company's mine are all equipped for hydraulicking. Their combined output in 1907 had a value of a few thousand dollars.

COPPER MINES.

According to returns from the smelters, Oregon produced 545,859 pounds of copper in 1907. Of this amount, by far the larger part was derived from the ores of Josephine County and the remainder from the ores of Grant County. The entire output of Josephine County came from one mine, the Queen of Bronze, in the Waldo district. Some good ore had been taken from several small mines adjacent to this one, but operations on these mines have been suspended for some time. During the summer of 1908 very little work was being done at the Queen of Bronze mine, but preparations were being made for more extensive developments.

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QUEEN OF BRONZE MINE.

The Queen of Bronze mine is located in sec. 36, T. 40 S., R. 8 W., about 6 miles from Waldo and 2 miles from Takilma. It is owned by the Takilma Smelting Company, of Colorado Springs, Colo., and was superintended by C. E. Tucker.

The rocks with which the ores are associated are gabbros, peridotites, and serpentine. These rocks are widespread in southwestern Oregon. The peridotite, which consists chiefly of enstatite and olivine, is in many places intruded in the gabbro; in other places the peridotite and gabbro appear to be products of differentiation of the same magma, there being no sharp line between those rocks which are rich in olivine and pyroxene but have no feldspar and those which are olivine gabbros and gabbros, the last named containing chiefly plagioclase feldspar and pyroxene but no olivine. Locally the peridotite grades into pyroxenite. The compositions and field relationships of these rocks clearly indicate that they are closely related genetically. In some places the peridotites and related rocks are fairly free from decomposition, but over large areas they have been altered to serpentine, which usually has a greenish-yellow color and shows slickensided surfaces. At a few places the serpentine is itself undergoing decomposition, one of the products of alteration being magnesite. The peridotites, gabbros, and serpentine almost everywhere shows the effects of earth movements. They are fractured, fissured, and jointed, and in many localities are decidedly brecciated. The soil formed from these rocks is in general of a reddish color and supports a scant vegetation.

The outcrops of the ore deposits consist of gossan, the oxidized materials varying in depth from a few feet to more than 100 feet. The ore bodies have no definite form but occur as irregular masses in the gabbro, the peridotite, and the serpentine. These masses or pockets of ore appear to have no definite relationships to one another but occur irregularly in the fractured and fissured rocks. Most of the ore bodies, however, that have been found on the Queen of Bronze and adjacent claims lie in a zone that extends for several miles in a north-south direction and has a width of less than 1 mile. The largest single body of unoxidized ore mined at the Queen of Bronze mine contained about 10,000 tons. Practically all of it came from a depth of less than 30 feet. Other masses of unoxidized ores have been taken from depths of about 100 feet. Although depths of about 300 feet have been reached in the workings, no important body of ore has been found below 125 feet. Several occurrences of slickensided ores were observed, and in some places the ore contains small veinlets of calcite.

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The unoxidized ore is chalcopyrite, with which are associated pyrite, pyrrhotite, and subordinate amounts of quartz and calcite. In the low-grade ores pyrite and pyrrhotite are the most abundant minerals. In addition to the copper content, the ores carry some gold and silver.

The oxidized ores are malachite, azurite, cuprite, tenorite (?), and chrysocolla. Of these the black ores, containing tenorite or chalcocite, are most abundant. Several thousand tons of oxidized ore has been mined. The average content in copper was more than 10 per cent. The lower limit of the oxidized ores is usually less than 90 feet from the surface, but some have been found at greater depths. In a small opening about 105 feet below the surface black oxide and small amounts of native copper were observed. The zone of oxidation is invariably deeper where the rocks have been serpentinized than where the country rocks are fairly fresh.

These ore bodies are apparently the result of precipitation from mineral-bearing solutions which entered the rocks after they had been fractured and fissured by earth movements. Whether these solutions were set free from cooling magmas as they solidified to form igneous rocks or whether they were of meteoric origin it is impossible to determine. Although dikes cutting the peridotite and gabbro were not observed in the vicinity of the mine, their presence in other areas of these rocks would suggest that the solutions may have been associated with the magmas from which the dikes were formed. In places in the serpentine below the zone of oxidation chalcopyrite with slickensided surfaces has frequently been found. The chalcopyrite appears to have been subjected to all the movements which accompanied the process of serpentinization. This indicates that the ores are older than the serpentine.

The mine is more than 20 miles from Grants Pass, which is the most accessible point on the railway. The only means of transportation between Grants Pass and the mine is by wagon; consequently the rates for hauling machinery, provisions, and other materials for the mine and coke for the smelter have been high. This fact has been unfavorable to the development of the property. The mine is situated on the slope of a ridge. The smelter is at the base of the slope 500 feet below the mine and 1½ miles from it. The ores, when taken from the workings, are trammed to bins, from which they are transferred to wagons and hauled to the smelter.

The equipment at the mine consists of three boilers, an air compressor, a hoist, and two machine drills. The mine has been developed by tunnels, drifts, and open cuts. The chief workings are related to two gossan-covered areas on the claim. The northern and more extensive workings are near the north boundary of the claim; the other workings are about 1,200 feet farther south.

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The northern workings consist of two tunnels, from which considerable drifting has been done, and a large open pit. The upper tunnel, which is about 400 feet long, enters the west slope of the ridge and runs eastward beneath an area of decomposed and brecciated gabbro, in which are oxidized ores. At no place does this tunnel have a vertical depth of more than 90 feet from the surface. In this tunnel and in drifts and winzes from it some large irregular-shaped masses of chalcopyrite, but practically no oxides, were obtained. From the tunnel an upraise was made to the oxidized ores. This upraise was then used as a chute. The oxidized ores were mined to the surface by overhand stoping, passed through the chute, and carried out by tram through the tunnel. Several thousand tons of oxidized ores were mined in this way, the large open pit thus formed having an area of about 120 by 120 by 80 feet. Where the tunnels and other workings were in the serpentine, great care had to be taken in timbering. The lower tunnel also enters the west slope and is about 190 feet below the upper tunnel. In it and in drifts from it more than 1,100 feet of work has been done. Only a small amount of ore was found in these workings.

The southern workings consist of a large open cut, a tunnel, which runs underneath this cut, and a 106-foot shaft. From the open cut about 10,000 tons of unoxidized ore, carrying about 7 per cent of copper, was taken. The zone of oxidation was only a few feet in depth. The ores mined were passed through a chute from the bottom of the pit to the tunnel and then trammed to the bins. From the tunnel and the shaft only a small amount of profitable ore was mined.

All the ores that have been mined have been smelted at the Takilma smelter, which is under the same ownership as the mine. The smelter is of the pyritic matte type and has a capacity of 100 tons a day. The charge used was about 1,500 pounds of ore, 350 pounds of limestone, and 200 pounds of coke. The limestone used had to be hauled about 2 miles. The matte from the ores smelted in 1907 contained about 40 per cent of copper.

The Queen of Bronze property was acquired in 1903 by the present owner. Only a small amount of development had been done on the property previous to its acquisition. In all about 30 claims are owned by the company. Including the cost of the smelter, more than $150,000 has been spent on the properties. Mr. Tutt, the president of the company, stated that more than 20,000 tons of ore had been smelted and that the average copper content had been about 8½ per cent. The gold content of the ores has been worth more than $3 a ton, the silver content about 17 cents a ton. Ore was first smelted from this property in 1904. The greatest production was in 1907.

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OTHER COPPER MINES.

As already stated, there are several small mines adjacent to the Queen of Bronze mine, and owned by Mr. Tutt and his associates. Considerable development has been done on these properties, and from three of them—the Cow Boy, the Lyttle, and the Mabel—about 4,000 tons of ore has been smelted. The characters of the ores, their modes of occurrence, and their associations are similar to those of the Queen of Bronze mine.

Some distance to the northeast of the Queen of Bronze mine is a prospect owned by Doctor Spence. On this property considerable work has been done and some good ore has been found.

PROSPECTS OF STIBNITE, JOSEPHINITE, AND CINNABAR.

Within the area here described stibnite, josephinite, and cinnabar have been found in small quantities.

A stibnite prospect is located in the SE. ¼ sec. 24, T. 40 S., R. 4 W., about 3 miles north of Watkins, on Applegate River. It is owned by C. M. Buck, of Watkins. The ore occurs in the fractures of a fine-grained brecciated greenstone. From a trench about 50 feet long and a tunnel about 25 feet long several tons of good ore has been mined. Where the ore is exposed the antimony sulphide is being changed to antimony oxide.

The mineral josephinite has been found only in the placers of Josephine Creek, in Josephine County. It is an alloy of iron and nickel, containing 60.47 per cent of the latter.[a] When the mineral is polished it has the appearance of metallic iron or nickel. Although it has not been found in the rocks, the mineral in the placers has probably come from the serpentine through which the stream has cut its channel.

A small prospect of cinnabar, the sulphide of mercury, is located on Palmer Creek, a western branch of Applegate River. Although a considerable amount of the mineral is reported to have been found with the gravels of the stream, very little has yet been found in the surrounding rocks.

[a] Am. Jour. Sci., 3d ser., vol. 43, p. 509.

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NOTES ON THE BOHEMIA MINING DISTRICT, OREGON.

By Donald Francis MacDonald.

INTRODUCTION.

The Bohemia mining district is in Lane and Douglas counties, west-central Oregon. It lies on Calapooya Mountain, in the western foothills of the Cascade Range. The district is about 30 miles southeast of Cottage Grove, a small town on the Southern Pacific Railroad. The Oregon and Southeastern Railroad runs from Cottage Grove to Disston, within 12 miles of the mines, which are reached by stage.

In August, 1908, the writer made a short stay in this district and incidentally to other work visited some of the larger mineral properties. For some of the data presented herein he is indebted to Mr. J. S. Diller, of the United States Geological Survey, who made a reconnaissance of the region in 1898,[a] and for many courtesies to Messrs. L. D. Ryan, F. J. Hard, W. W. Warner, and other mining men of the district.

PHYSIOGRAPHY AND GENERAL GEOLOGY.

The relief of the district is pronounced. Several peaks are more than 6,000 feet high, and the elevation of the lowest valleys is less than 2,000 feet. This bold relief is the result of mountain glaciation and stream erosion. The luxuriant vegetation due to the humid climate has somewhat masked the geologic features of the region. Great forests clothe the mountain slopes and the region is notable for its timber value.

The rocks of the district are andesitic lavas and tuffs of Tertiary age, which are cut by dacite porphyry and probably by basalt. The andesites are the most abundant rocks. Seven consecutive flows, aggregating 500 feet in thickness, appear on the south face of Bohemia Mountain. They vary from light to dark gray in color and in hand specimens show small elongated phenocrysts of feldspar and very small greenish crystals of pyroxene or chlorite. In weathering the rock assumes a light-gray to buff color, the feldspars becoming white and powdery. Good exposures of andesite are shown on Bohemia, Elephant, Fairview, and Grizzly mountains.

[a] The Bohemia mining region of western Oregon: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, pp. 7–64.

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The tuffs, in the main, are of andesitic composition and at many places are interbedded with andesite flows. A tuff composed of coarse fragments occurs near the White Ghost claim on City Creek. Fine tuff interbedded with lava is shown in the crosscut to No. 2 level in the Noonday mine. The slope east of Horseheaven Creek shows a considerable area of light-gray stratified tuffs. Fine gray banded tuffs were seen on the slopes below Judson Rock. These tuffs are contemporaneous with the andesites, particularly with the later flows.

A light-gray rock, probably dacite porphyry, cuts the darker andesites and tuffs in many places. This rock on fresh fracture shows minute aggregations of quartz, larger crystals of feldspar, and small dark crystals of pyroxene and hornblende. The fine groundmass between the large crystals is gray to slightly greenish, the green tinge being due to the presence of chlorite. This dacite porphyry cuts andesites and interbedded tuffs at several places along the road about halfway between Disston and Orseco. It also occurs within half a mile of the Musick mine, both to the northeast and to the southeast.

Basalt occurs in one or two small outcrops. It is a fine-grained, dark lava, best shown on the south edge of Bohemia Mountain. Its small outcrop suggests that it is intrusive in the andesite.

ORE DEPOSITS.

The ore deposits of this district are fissure veins, which cut the andesites and tuffs. Small sulphide impregnations also occur in the vicinity of altered diabasic dikes, but they have no economic value. The general strike of the veins is north to northwest, with a dip of 60° to 85°. They vary from 1 foot to 12 or 15 feet in width. Some are single veins; others consist of two or more parallel veins, separated by a few inches to a few feet of highly altered country rock. At the Musick mine there are three parallel veins, 1 to 4 feet in width, separated by thin walls of altered country rock. Only the fissure veins which have suffered postmineral fracturing have produced profitable ore. These veins, because of their oxidized and easily workable condition, gave good returns in free gold in their upper workings. Veins which have not been fractured since they were mineralized, or which are situated in regions of maximum erosion, such as old glacial cirques, show sulphide ores at the surface. They are tightly cemented and relatively impermeable and represent the conditions of mineralization that prevail in all the veins below the oxidized zone. The minerals which they contain are sphalerite, pyrite, a little galena, and very little chalcopyrite, with a gangue of quartz, altered country rock, and some calcite. So far these veins have not been found profitable, because their sulphide ore can not be cheaply treated, the tightness with which the ore is cemented makes mining more expensive, and the gold tenor is less than that of the oxidized material.

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HYDROTHERMAL METAMORPHISM.

In the vicinity of the veins the mineralizing solutions have greatly altered the country rock. Several hundred feet distant from a vein the dark color of the rock is in many places changed to a greenish tinge, while close to the deposit it is gray to buff in color, has a clayey appearance, and crumbles easily. The pattern of the rock is fairly well preserved, however, the outlines of the feldspar phenocrysts being clearly visible, though the feldspar material has been changed to a white or yellowish powder.

Under the microscope it is seen that the basic feldspars have altered into sericite, calcite, and quartz, the quartz, however, being in relatively small quantity. The ferromagnesian minerals have been changed to calcite and the iron in them appears now as limonite or hematite. Farther away from the vein, where metamorphism was less intense, these minerals have reached only the chloritic stage of alteration. In many veins soft disintegrated country rock forms a considerable part of the vein matter. An examination of this material showed that near the surface it is composed essentially of very fine granules of quartz with considerable iron-stained kaolin. At greater depth the same rock contains an abundance of sericite and calcite with very little kaolin.

SECONDARY ALTERATION AND ENRICHMENT.

Some of the veins were brecciated after they were filled, and as a result oxygenated surface waters were able to percolate downward along the fractured zone. The ores were thus oxidized and sulphides leached out to depths of 100 to 300 feet, depending on the degree of brecciation and the rate of erosion. The gold occurred as threads and filaments included in the pyrite. The pyrite was leached away, leaving the relatively insoluble gold and some iron oxide occupying a part of the small cavity left in the vein material. This process brought about an association of free gold with iron-stained, spongy quartz and enriched the ore by leaching out the valueless sulphides. It also rendered the ore soft and porous, so that it is much more cheaply mined and milled than the unaltered ore.

Small local enrichments of free gold occur at the junctions of fissures, pyrite being abundant at these junctions, as shown by the mass of iron oxide left. It is probable that the smaller particles of gold were dissolved from the upper parts of the vein by the ferric sulphate solutions of oxidized pyrite and were precipitated by the local masses of pyrite below.

Some secondary sulphides were observed, but these are of no commercial value. They consist of pyrite crystals deposited in cracks in primary pyrite and of very small masses of sphalerite and galena. Other secondary minerals noted were calcite and, rarely, cerusite.

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MINING DEVELOPMENT.

Gold was first discovered in Bohemia in 1858. In 1875 the first mill, a five-stamp battery, was built on the Knott claim. From 1877 to 1891 little was done in the district. In the nineties the Musick, Champion, Noonday, Vesuvius, and several other mines became active, and mills aggregating 35 or more stamps were built. At the time of visit, in August, 1908, no ore was being milled in the district, nor had any milling been done since the previous summer. Several companies, however, had men employed in prospecting and development.

Figures for the total output of the camp are not available. As nearly as can be judged from the statistics published in "Mineral Resources of the United States," and from verbal reports, the total product is probably between $300,000 and $400,000, mainly in free gold. Although some rich shoots occur locally, the average tenor of the ore is low, generally running $3 to $5 a ton. The soft, spongy, iron-stained vein material is cheaply mined and milled. The cost of mining is from $1.50 to $2 a ton, and of milling little over 50 cents a ton. The concentrates range in value from $20 to $70 a ton and consist in the main of auriferous pyrite, with silver and a little lead and copper. Values less than $25 a ton can not be profitably shipped because of present high freight rates.

The principal mines of the region which have produced values are the Musick, Champion, Vesuvius, Noonday, Helena, and California, and there are others of lesser note. The Musick leads in development, with about a mile of drifts along six 50-foot levels. Of these, levels 4 and 6 are reached by short crosscuts which tap the vein from the basin at the head of City Creek. About 2,000 feet to the west, on the other slope of the divide, a portal from one of the lower drifts opens out close to a good stand of mining timber. A shaft 80 feet deep connects directly with the two upper levels and through various stopes with most of the lower workings, thus giving good ventilation to the mine. Most of the ore was hauled out at the lower level, which attains a maximum depth of about 300 feet.

The Champion, Vesuvius, and Noonday have each about half a mile of workings. In the Champion most of the development work has been done on two levels, the lower of which attains a maximum depth of about 200 feet and is reached by a crosscut a few hundred feet in length through which all the ore is brought out. A considerable amount of stoping has been done, particularly where the greatest oxidation occurred. The lower workings here show considerable amounts of primary sulphides. The Vesuvius has been worked from several levels to a depth of about 300 feet and has many stopes. The steep slope on which it is situated has facilitated

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its development by tunnels and has afforded a gravity transfer for the ore from stope to mill, as well as good ventilation and drainage for all the workings. The Noonday has three principal levels, all tapped by crosscuts from the steep slope of the Horseheaven basin; the lowest level attains a maximum depth of about 300 feet. Considerable stoping was done and the ore from the stopes was sent down to the mill on an aerial tramway about one-third of a mile in length. The Helena has more and the California somewhat less than 1,000 feet of workings. Both are developed by tunnels which will attain 100 to 300 feet of depth. The Helena has two levels and has produced some very rich specimen ore.

The ore from the Musick mine was hauled over a practically level electric tramway about a mile in length and dumped into the ore bins of the Champion mine. Thence the ore of both mines was sent down to the mill on a steep incline, 3,400 feet long. Haulage was effected by an endless cable to which the mine cars were attached by means of an automatic grab, the loaded cars going down pulling the empties up. The Musick-Champion mill, the largest in the district, has 30 stamps and is run by a water-driven electric generating plant located on Frank Bryce Creek, 7 miles below the mine. It handled the ore from both the Musick and Champion mines. The electric plant was designed to develop 300 horsepower and to operate the stamp mill, a small sawmill, and a local electric-light plant and to furnish mine power. A small auxiliary steam plant is provided for use in case of need. Other milling plants in the district are a 10-stamp mill at the Vesuvius mine, a 5-stamp mill at the El Calado property, and a 20-stamp mill on the Noonday group.

SILVER AND COPPER PROSPECTS.

The Riverside and Oregon-Colorado claims are promising copper prospects which show some good chalcopyrite ore and are located on strong veins. The Combination property covers a somewhat extensive lode, consisting of one large vein and some smaller veins, and is said to have produced ore which assayed more than 25 ounces of silver to the ton.

FUTURE OF THE DISTRICT.

The Bohemia district contains many well-defined veins and lodes. Many of those which show on the surface have not yet been explored, and no doubt many more are obscured by the dense vegetation which covers a large part of the district. It seems reasonable to suppose that other mines will yet be opened, and will find workable gold ore at least in the upper and oxidized portion of the veins. Workable bodies of copper and silver may possibly be discovered in the district.

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FAULTING AND VEIN STRUCTURE IN THE CRACKER CREEK GOLD DISTRICT, BAKER COUNTY, OREGON.

By J. T. Pardee.

INTRODUCTION.

The Cracker Creek mining district is situated in the northwestern portion of Baker County, Oreg. It is a small integral part of the Blue Mountain gold belt, which has been described by Lindgren,[a] and as generally understood comprises the drainage basins of Cracker and Fruit creeks. The town of Bourne, 6 miles north of Sumpter, is the principal settlement within the district. The principal mines are the North Pole, Eureka and Excelsior, Columbia, and Golconda, all located, from northeast to southwest in the order named, on one persistent fissure, the North Pole-Columbia vein, or "mother lode," as it is locally designated. At present the Columbia is the only producing mine in the district, but the suspension of operations in most of the others is believed to be temporary and not caused by exhaustion of the ore bodies. In addition to those above mentioned, there are a number of smaller mines and prospects on which annual assessment and considerable development work is being done. Time in which to visit all the mines was not available, but in November, 1908, during the progress of field work in the Sumpter quadrangle, in the northern part of which this district lies, advantage was briefly taken of opportunity to visit the underground workings of the Columbia and North Pole mines, to the managers of which, Mr. Frank S. Baillie and Mr. Emil Melzer, respectively, acknowledgment is gratefully made for courtesies extended.

The aggregate production of the mines on the "mother lode" is estimated to be at least $7,000,000.

TOPOGRAPHY.

All of the district is mountainous. The streams have rather steep gradients and flow through valleys which are for the most part V-shaped, but some of which are U-shaped in their upper courses.

[a] Lindgren, Waldemar, The gold belt of the Blue Mountains of Oregon: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1901, pp. 551–776.

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The dividing ridges are steep and rugged, with narrow, somewhat serrate summits. The minor details of the sculpture express the variations in the hardness of the underlying rocks. Down cutting of the stream beds appears to be generally still in progress. The average depth of the valleys is from 1,000 to 2,000 feet. The altitude of Bourne is 5,400 feet; that of the junction of Cracker and Silver creeks, the lowest point in the district, 5,000 feet; that of the peak at the head of Rock and Sardine creeks, the highest point in the district, 8,400 feet.

The principal topographic features of the area dealt with in this paper are shown in somewhat generalized fashion in figure 3. The spur trending south-southwestward from Elkhorn Ridge and terminating at Bourne has the local name of North Pole Hill. The ridge dividing Cracker and Fruit creeks is locally named at its southern extension Columbia Hill, and this name may be conveniently extended to the whole ridge.

GEOLOGY.

STRATIGRAPHY.

The rocks most extensively developed about the Cracker Creek mines are argillaceous and siliceous sediments, nonfossiliferous so far as known, and very fine grained throughout. The composition of the beds varies from that of chert consisting almost wholly of silica to that of highly aluminous blue-black slate. These types, however, are rarely found in complete purity; they grade one into the other, and are at many places interlaminated, the cherts in particular being divided into thin sheets and lenses by argillaceous partings. Seen in distant views, the weathered outcrops of the sediments everywhere appear rather dark in hue and more or less rusty with oxide of iron. The impression conveyed by a cursory examination is one of monotony and of a lack of sharp lithologic distinctions. Only long-continued and careful observation made it possible to recognize lithologic subdivisions of the stratigraphic column, a task which it was necessary to accomplish before the structure could be deciphered. The series appears to be conformable. It is exposed over the greater portion of the district in the form of a salient surrounded by intrusives. (See fig. 3.)

The rocks of igneous origin are intrusive granodiorite, surrounding the sedimentary area on the north and northwest; some dikes, observed to cut both the argillite and the granodiorite, varying in thickness from a few inches to 20 feet or more, that appear to be mainly altered feldspar porphyries; a few aplitic dikes; some small masses of serpentine; and a greenstone, probably an interbedded lava or intrusive sill. This last-named rock is most conveniently con-

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sidered in connection with the sedimentary rocks, which are probably of Paleozoic age.[a]

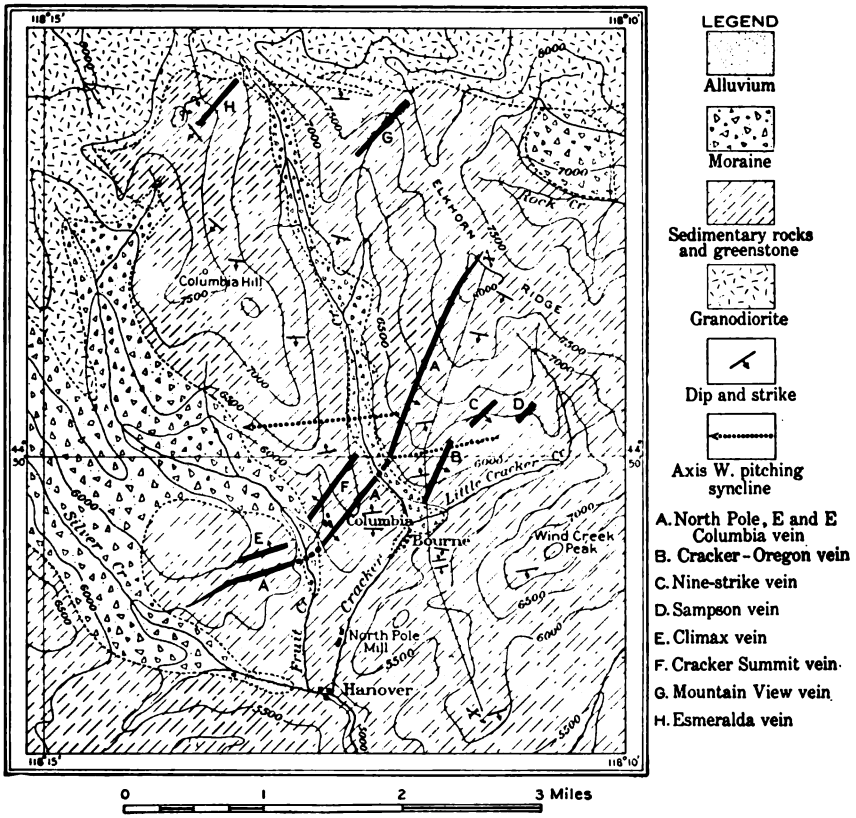

FIGURE 3.—Geologic sketch map of part of Cracker Creek mining district, Baker County, Oreg. Topography from Sumpter atlas sheet.

The following measurements are provisional and subject to correction:

Section of sedimentary rocks and greenstone in Cracker Creek mining district.

[Beds numbered in order of age.]

	Feet.
8. Light to blue-gray siliceous shale. Laminæ 1 to 5 inches thick, irregularly swelling and pinching, separated by very thin dark partings. On weathered surface numerous lighter-colored spots are etched, forming slight depressions and giving outcrops a mottled appearance. Prominent outcrops	100
7. Dark-gray, thinly laminated, rather siliceous argillite, locally mottled as in No. 8 above. Middle portions black with slaty cleavage. Inconspicuous outcrops	600

[a] Lindgren, Waldemar, op. cit.

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	Feet.
6. Blue-gray, indistinctly bedded siliceous shale, locally mottled on weathered surface. Moderately conspicuous outcrops	150
5. Dark-gray to black argillite, thinly laminated, conspicuously mottled. Very subordinate outcrops	700
4. Greenstone, a hard, tough, heavy, greenish, massive crystalline rock, of varying texture. Exposed surfaces usually etched, showing irregular rough "warty" prominences of dark-green hornblende, between which are light-gray depressions, these features here and there so arranged as to faintly suggest bedding. Prominent cliffy outcrops	600
3. Black, slaty, thinly laminated argillite with some indistinctly bedded, rather siliceous layers, having mottled weathered surfaces. Inconspicuous outcrops	350
2. Light to warm gray, almost purely siliceous sediments. Laminæ 1 to 3 inches thick; otherwise as in No. 8; prevailingly mottled at top. Forms prominent outcrops	100
1. Prevailingly siliceous, gray to dark-gray sediments, rather indistinctly bedded as a rule, but containing a few beds 4 to 10 feet thick and one 80 feet thick, closely resembling No. 2 above, except that mottling is less conspicuous or absent. Contains also a few thin argillaceous beds. Weathered surfaces gray brown in upper portion to red brown in lower. Prominent outcrops	400+
	3,000

STRUCTURE.

FOLDING.

The most readily noticeable structural feature of the more siliceous of these beds consists of the contortions and small close folds they everywhere exhibit. The black argillites have a slaty cleavage that as a rule coincides with the bedding. Some of them are closely folded also, but as their bedding is less distinct than that of the siliceous rocks their structure is more obscure. The thickening due to small folds has not been estimated, and is therefore not eliminated in the tabular section. As a rule the strike of the beds is N. 80° E. in the southern portion of the district, gradually changing to northwest in the northern portion. The dips are prevailingly south, with local exceptions caused by a westward-pitching syncline exposed in the southern portions of North Pole and Columbia hills. (See figs. 3 and 4.)

FAULTING.

The most noteworthy structural feature is faulting of an extreme distributive type, which is developed throughout the district. This faulting is so common that portions of the district, as for instance the

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northern half of Columbia Hill and Elkhorn Ridge, from the summit of North Pole Hill northward to the intrusive contact, may be said to resemble huge fault breccias. The dimensions of the faults descend to the microscopic, and nearly every joint and cleavage plane shows polishing or striæ as evidence of movement.

The observed indications of faulting are the following: (1) Beds are in contact out of their normal sequence. The satisfactory identification of the different beds in this district, where sharp lithologic distinctions are lacking and discontinuous exposures the rule, requires careful scrutiny, and the definite location of fault contacts is best effected by carefully following the more prominently cropping siliceous beds. (2) There are numerous fault breccias, the fragments of which, usually distinguishable from other products of disruption by their polished or striated surfaces, are generally distributed in the surface mantle and, where found in place or nearly so, as on some ridge summits, indicate the positions of faults. (3) Notches, trenches, ravines, and offsets in ridges commonly indicate the positions of faults in this district. (4) Many fault planes may be directly observed on cliff faces and in drifts, pits, etc.

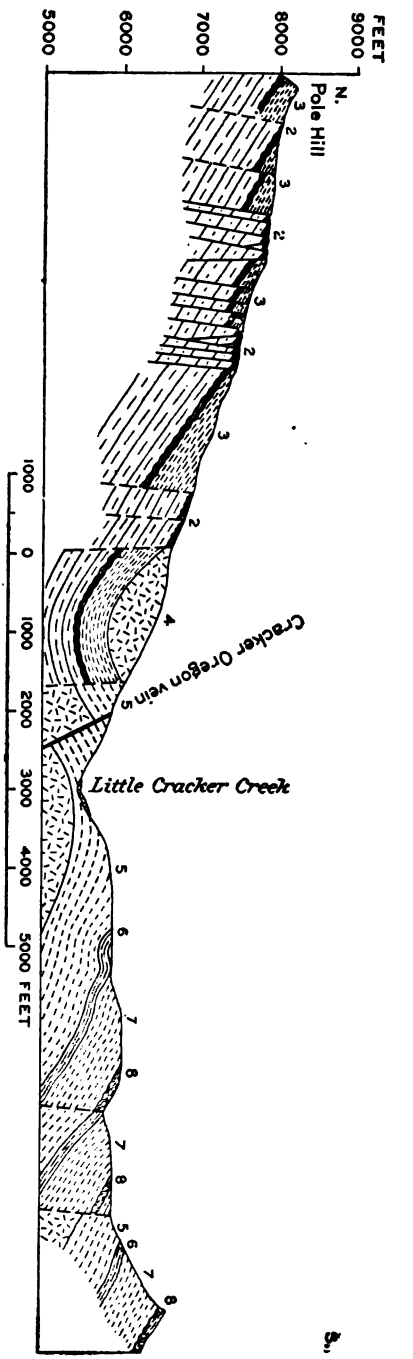

FIGURE 4.—Section along line A-B, figure 3. Numbers refer to section on pages 87 and 88.

All faults in the district whose attitude has been determined are normal, and steep dips are the rule. Most of them may

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be grouped, as regards strike only, in an approximately north-south system; an east-west system, observed in some instances to displace the former; and a northeast-southwest system that includes the quartz veins. In the first two of these groups the movement on any one fault plane may commonly be measured in inches, and the maximum observed does not exceed 100 feet. The sum of these small movements is, however, considerable. For instance, the faults of the east-west system on North Pole Hill within a horizontal distance of 1 mile effect an aggregate downthrow to the north of approximately 2,000 feet. (See fig. 4.) But this summation, it should be noted, takes no account of the horizontal component, which, as shown by the pitch of striæ, enters into the movement in nearly every fault plane.

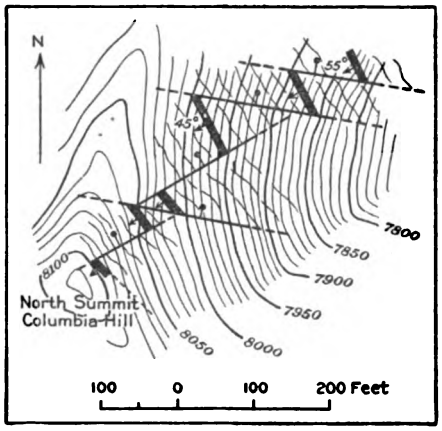

FIGURE 5.—Detail of faulting northeast of Columbia Hill, Baker County, Oreg.

The detail of some of the less complex fault zones may, in favorable places, be mapped, and one near the north summit of Columbia Hill is shown in figure 5. Many of the fault zones are composed of smaller units than this one. An example is one of the east-west faults just south of the lower summit of Columbia Hill. Its aggregate vertical displacement (the horizontal movement not having been estimated) is 400 feet, distributed along a large number of parallel planes, lying 1 inch to a few feet apart, through a horizontal distance of 600 feet.

VEIN SYSTEM.

Only the most superficial observations were made on the smaller veins, the locations of some of which are indicated in figure 3. The Cracker Oregon vein is 4 to 8 feet wide and dips steeply to the southeast. The Cracker Summit vein is 4 to perhaps 12 feet wide and dips 50° to 70° NW. Both are said to have produced pay ore; their vein filling resembles that of the "mother lode" and their walls bear evidence of movement. The Cracker Summit vein has at several points been displaced by faults of the other groups, but the exact details of the faulting have not yet been worked out.

The "mother lode" stands out as a most prominent economic and structural feature. It is a normal fault extending beyond the limits of the district. The portion of it here particularly referred to is that extending from the Columbia shaft to the limit of the North Pole stopes, a distance of 7,500 feet. On this portion of the vein are

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located the Columbia, Eureka and Excelsior, and North Pole mines, from southwest to northeast in the order named.

The displacement along this fracture, which in the North Pole dips 70° SE. and strikes N. 34° E., was approximately determined where it crosses Columbia Hill. Here bed No. 4 of the section on pages 69–70 forms the hanging wall and is in contact with bed No. 2 on the foot wall, indicating a vertical displacement of at least 400 feet. But in addition to the vertical throw the fault causes a horizontal displacement of approximately 1,800 feet. This estimate is obtained from the present relative positions of the detached portions of the syncline briefly referred to above and indicated in figures 3 and 4, which the fault cuts nearly at right angles to its axis. The axis of this trough trends approximately east and west and was originally continuous. At present the intersection of the axial plane of the North Pole Hill half of the trough with that of the vein lies about 1,800 feet south-southwest of the intersection of the corresponding plane in the Columbia Hill portion of the trough with that of the vein. This estimate is subject to modification by more careful measurements, but not sufficiently so to disprove the statement that there has been a horizontal displacement of considerable magnitude. The horizontal movement is further indicated by striæ within the vein, as described below. The vein may be said to divide the district into two fault blocks. With respect to the northwestern or Columbia Hill block, the southeastern or Bourne block has settled and moved southwest by south, or along a line lying in the plane of the vein and pitching gently to the southwest.

The large amount of development work that has been done on the "mother lode" offers excellent opportunity for investigation of the structure due to complex movements within the vein.

The Columbia mine is opened by three adit levels and a 900-foot vertical shaft with which crosscuts and drifts connect at each 100 feet. The aggregate of development is stated by Mr. Baillie to be, in drifts and crosscuts, 19,470 feet; in shaft, raises, and stopes, 29,274 feet; total, 48,744 feet.

The shaft is sunk in the hanging wall 45 feet from the vein, which it penetrates at a depth of 800 feet, thus showing the dip of the vein here to be about 86½° SE. Its strike is N. 34° E. Northeast of the shaft the vein is well defined and 20 to 100 feet wide. The ore shoots, 3 to 8 feet in width, are found on the foot wall in all but the upper (adit) levels, where they have crossed to the hanging wall. The pay ore is usually separated from more barren quartz by walls lined with thinly-laminated black gouge. The laminæ are mostly striated. In many places the striæ on one side of the lamina pitch at variance with those on the other side. The directions of movement thus indi-

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cated vary from vertical to horizontal, the horizontal component usually predominating. The ore body itself is separated into overlapping wedges or thick lenslike masses by seams of black, laminated, striated gouge. About 200 feet south of the shaft the vein loses its identity in a zone characterized by a great number of faults, most of which strike southwest to west and dip 45° N. or S. The gouge linings of these faults nowhere fail to exhibit evidences of movement as above described. Within this zone isolated masses of ore are found.

The North Pole mine is not at present in operation, having closed down last August. It is developed by five adit levels and one intermediate level, aggregating 12,500 feet, and a large extent of crosscuts and stopes. At 1,800 feet from the mouth of tunnel No. 1 a fault, whose course is N. 18° W. and dip 60° W., displaces the ore shoot 45 feet to the southeast. On following this fault for about 500 feet to the intermediate level, the displacement is noted to be small, and the slip appears to coincide with a flat wall forming the lower boundary of the ore shoot for a distance of about 1,200 feet farther on. This ore body widens above, attaining a maximum of 25 feet just under tunnel No. 3, where a cross section of the vein is as follows:

Section of vein of North Pole mine.

	Feet.
Foot wall; dark-gray siliceous shale.	
Brecciated quartz in black gouge	3
White quartz	40
Finely brecciated unconsolidated ("sugar") quartz	15
Low-grade vein quartz	15
Ore	25
	98

These divisions are separated by polished or striated walls approximately parallel to those of the main vein and bearing abundant, black, laminated, obliquely striated gouge. This ore body abruptly ends to the northeast against a fault plane, striking N. 80° W. and dipping 45° S., which does not penetrate the main hanging wall. Neither does the foot wall appear to have been displaced where the drift turns to it about 120 feet farther on. From this point northeastward for about 400 feet to the face of the drift the foot wall carries small masses of ore that usually exhibit a tendency to branch and disappear in seams leading obliquely upward toward the opposite wall. In the main stope just referred to the ore lies on either wall or occupies intermediate positions. In some places the ore is observed to cross from one position to another on transverse, southwestward-dipping, obliquely striated fault planes that do not pass without the vein.

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PRACTICAL CONCLUSIONS.

The results of structural study in the Cracker Creek district indicate that the "mother lode" is not notably displaced by transverse faults. Within the vein itself, however, there are faults which affect the ore bodies. Some of the smaller veins have been offset by faulting. The fact that the faults of known attitude are normal, and that in the movement upon them the horizontal component is commonly as important as the vertical one, should be taken into account in the development of such of the ore bodies as have been displaced.

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SURVEY PUBLICATIONS ON GOLD AND SILVER.

The following list includes the more important publications by the United States Geological Survey, exclusive of those on Alaska, on precious metals and mining districts. Certain mining camps, while principally copper or lead producers, yield also smaller amounts of gold and silver. Publications on such districts are listed in the bibliographies for copper and for lead and zinc. When two metals are of importance in a particular district, references may be duplicated. For names of recent geologic folios in which gold and silver deposits are mapped and described, reference should be made to the table in the "Introduction" to this volume.

These publications, except those to which a price is affixed, may be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.; the monographs from either the Director or the Superintendent of Documents.

ARNOLD, RALPH. Gold placers of the coast of Washington. In Bulletin No. 260, pp. 154–157. 1905. 40c.

BAIN, H. F. Reported gold deposits of the Wichita Mountains [Okla.]. In Bulletin No. 225, pp. 120–122. 1904. 35c.

BALL, S. H. Geological reconnaissance in southwestern Nevada and eastern California. In Bulletin No. 285, pp. 53–73. 1906. Also Bulletin No. 308. 218 pp. 1907.

BARRELL, JOSEPH. Geology of the Marysville mining district, Montana. Professional Paper No. 57. 178 pp. 1907.

——— (See also Weed, W. H., and Barrell, J.)

BECKER, G. F. Geology of the Comstock lode and the Washoe district; with atlas. Monograph III. 422 pp. 1882. $11.

——— Gold fields of the southern Appalachians. In Sixteenth Ann. Rept., pt. 3, pp. 251–331. 1895.

——— Witwatersrand banket, with notes on other gold-bearing pudding stones. In Eighteenth Ann. Rept., pt. 5, pp. 153–184. 1897.

——— Brief memorandum on the geology of the Philippine Islands. In Twentieth Ann. Rept., pt. 2, pp. 3–7. 1900.

BOUTWELL, J. M. Economic geology of the Bingham mining district, Utah. Professional Paper No. 38, pp. 73–385. 1905.

——— Progress report on Park City mining district, Utah. In Bulletins No. 213, pp. 31–40 (25c.); No. 225, pp. 141–150 (35c.); No. 260, pp. 150–153 (40c.).

CALKINS, F. C. (See Ransome, F. L., and Calkins, F. C.)

CALKINS, F. C., and MACDONALD, D. F. A geologic reconnaissance in northern Idaho and northwestern Montana. Bulletin No. 384.

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COLLIER, A. J. Gold-bearing river sands of northeastern Washington. In Bulletin No. 315, pp. 56–70. 1907.

CROSS, WHITMAN. General geology of the Cripple Creek district, Colorado. In Sixteenth Ann. Rept., pt. 2, pp. 13–109. 1895. $1.25.

——— Geology of Silver Cliff and the Rosita Hills, Colorado. In Seventeenth Ann. Rept., pt. 2, pp. 269–403. 1896.

CROSS, WHITMAN, and SPENCER, A. C. Geology of the Rico Mountains, Colorado. In Twenty-first Ann. Rept., pt. 2, pp. 15–165. 1900.

CURTIS, J. S. Silver-lead deposits of Eureka, Nev. Monograph VII. 200 pp. 1884.

DILLER, J. S. The Bohemia mining region of western Oregon, with notes on the Blue River mining region. In Twentieth Ann. Rept., pt. 3, pp. 7–36. 1900. $1.50.

——— Mineral resources of the Indian Valley region, California. In Bulletin No. 260, pp. 45–49. 1905. 40c.

——— Geology of the Taylorsville region, California. Bulletin No. 353. 128 pp. 1908.

DILLER, J. S., and KAY, G. F. Mines of the Riddles quadrangle, Oregon. In Bulletin No. 340, pp. 134–151. 1908.

ECKEL, E. C. Gold and pyrite deposits of the Dahlonega district, Georgia. In Bulletin No. 213, pp. 57–63. 1903. 25c.

EMMONS, S. F. Geology and mining industry of Leadville, Colo.; with atlas. Monograph XII. 870 pp. 1886. $8.40.

——— Progress of the precious-metal industry in the United States since 1880. In Mineral Resources U. S. for 1891, pp. 46–94. 1892. 50c.

——— Economic geology of the Mercur mining district, Utah. In Sixteenth Ann. Rept., pt. 2, pp. 349–369. 1895. $1.25.

——— The mines of Custer County, Colo. In Seventeenth Ann. Rept., pt. 2, pp. 411–472. 1896. $2.35.

——— (See also Irving, J. D., and Emmons, S. F.)

EMMONS, S. F., and IRVING, J. D. Downtown district of Leadville, Colo. Bulletin No. 320. 72 pp. 1907.

EMMONS, W. H. The Neglected mine and near-by properties, Colorado. In Bulletin No. 260, pp. 121–127. 1905. 40c.

——— Ore deposits of Bear Creek, near Silverton, Colo. In Bulletin No. 285, pp. 25–27. 1906. 60c.

——— The Granite-Bimetallic and Cable mines, Phillipsburg quadrangle, Montana. In Bulletin No. 315, pp. 31–55. 1907.

——— Gold deposits of the Little Rocky Mountains, Montana. In Bulletin No. 340, pp. 96–116. 1908.

——— (See also Ransome, F. L., and Emmons, W. H.)

EMMONS, W. H., and GARREY, G. H. Notes on the Manhattan district, Nevada. In Bulletin No. 303, pp. 84–93. 1907.

GALE, H. S. The Hahns Peak gold field. In Bulletin No. 285, pp. 28–34. 1906. 60c.

——— Gold placer deposits near Lay, Routt County, Colo. In Bulletin No. 340, pp. 84–95. 1908.

GARREY, G. H. (See Emmons, W. H., and Garrey, G. H.; Spurr, J. E., and Garrey, G. H.)

GRATON, L. C. Reconnaissance of some gold and tin deposits of the southern Appalachians; with notes on the Dahlonega mines, by Waldemar Lindgren. Bulletin No. 293. 134 pp. 1906.

——— (See also Lindgren, W., and Graton, L. C.)

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HAGUE, ARNOLD. Geology of the Eureka district, Nevada. Monograph XX. 419 pp. 1892. $5.25.

HAHN, O. H. The smelting of argentiferous lead ores in the Far West. In Mineral Resources U. S. for 1882, pp. 324–345. 1883. 50c.

IRVING, J. D. Ore deposits of the northern Black Hills. In Bulletin No. 225, pp. 123–140. 1904. 35c.

——— Ore deposits of the Ouray district, Colorado. In Bulletin No. 260, pp. 50–77. 1905. 40c.

——— Ore deposits in the vicinity of Lake City, Colo. In Bulletin No. 260, pp. 78–84. 1905. 40c.

——— (See also Emmons, S. F., and Irving, J. D.)

IRVING, J. D., and EMMONS, S. F. Economic resources of northern Black Hills. Professional Paper No. 26, pp. 53–212. 1904.

KAY, G. F. (See Diller, J. S., and Kay, G. F.)

LINDGREN, WALDEMAR. The gold-silver mines of Ophir, Cal. In Fourteenth Ann. Rept., pt. 2, pp. 243–284. 1894. $2.10.

——— The gold-quartz veins of Nevada City and Grass Valley districts, California. In Seventeenth Ann. Rept., pt. 2, pp. 1–262. 1896. $2.35.

——— The mining districts of the Idaho Basin and the Boise Ridge, Idaho. In Eighteenth Ann. Rept., pt. 3, pp. 625–736. 1898. $2.15.

——— The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho. In Twentieth Ann. Rept., pt. 3, pp. 75–256. 1900. $1.50.

——— The gold belt of the Blue Mountains of Oregon. In Twenty-second Ann. Rept., pt. 2, pp. 551–776. 1902.

——— Mineral deposits of the Bitterroot Range and the Clearwater Mountains, Montana. In Bulletin No. 213, pp. 66–70. 1903. 25c.

——— Tests for gold and silver in shales from western Kansas. Bulletin No. 202. 21 pp. 1902. 5c.

——— The production of gold in the United States in 1904. In Bulletin No. 260, pp. 32–38. 1905. 40c.

——— The production of silver in the United States in 1904. In Bulletin No. 260, pp. 39–44. 1905. 40c.

——— The Annie Laurie mine, Piute County, Utah. In Bulletin No. 285, pp. 87–90. 1906. 60c.

——— Notes on the Dahlonega mines. In Bulletin No. 293, pp. 119–128. 1906.

——— A geological analysis of the silver production of the United States in 1906. In Bulletin No. 340, pp. 23–35. 1908.

LINDGREN, WALDEMAR, and GRATON, L. C. Mineral deposits of New Mexico. In Bulletin No. 285, pp. 74–86. 1906. 60c.

LINDGREN, WALDEMAR, and RANSOME, F. L. The geological resurvey of the Cripple Creek district. Bulletin No. 254. 36 pp. 1905.

——— ——— Geology and gold deposits of the Cripple Creek district, Colorado. Professional Paper No. 54. 516 pp. 1906.

LINDGREN, WALDEMAR, and others. Gold and silver. In Mineral Resources U. S. for 1906, pp. 111–371. 1907. 50c.

——— and others. Gold and silver. In Mineral Resources U. S. for 1907, pt. 1, pp. 111–135. 1908.

LORD, E. Comstock mining and miners. Monograph IV. 451 pp. 1883. $1.50.

MACDONALD, D. F. Economic features of northern Idaho and northeastern Montana. In Bulletin No. 285, pp. 41–52. 1906. 60c.

——— (See Calkins, F. C., and MacDonald, D. F.)

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McCaskey, H. D. Notes on some gold deposits of Alabama. In Bulletin No. 340, pp. 36–52. 1908.

Nitze, H. B. C. History of gold mining and metallurgy in the Southern States. In Twentieth Ann. Rept., pt. 6, pp. 111–123. 1899.

Penrose, R. A. F., Jr. Mining geology of the Cripple Creek district, Colorado. In Sixteenth Ann. Rept., pt. 2, pp. 111–209. 1895. $1.25.

Pirsson, L. V. (See Weed, W. H., and Pirsson, L. V.)

Purington, C. W. Preliminary report on the mining industries of the Telluride quadrangle, Colorado. In Eighteenth Ann. Rept., pt. 3, pp. 745–850. 1898. $2.15.

Ransome, F. L. Report on the economic geology of the Silverton quadrangle, Colorado. Bulletin No. 182. 265 pp. 1901. 50c.

——— The ore deposits of the Rico Mountains, Colorado. In Twenty-second Ann. Rept., pt. 2, pp. 229–398. 1902.

——— Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada. In Bulletin No. 303, pp. 7–83. 1907.

——— Geology and ore deposits of Goldfield, Nev. Professional Paper No. 66. 1909.

——— (See also Lindgren, Waldemar, and Ransome, F. L.)

Ransome, F. L., and Calkins, F. C. Geology and ore deposits of the Coeur d'Alene district, Idaho. Professional Paper No. 62. 1908.

Ransome, F. L., and Emmons, W. H. Geology and gold deposits of the Bullfrog district, Nevada. (In preparation.)

Schrader, F. C. Mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz. In Bulletin No. 340, pp. 53–84. 1908.

——— The mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz. (In preparation.)

Schultz, A. R. Gold developments in central Uinta County, Wyo., and at other points on Snake River. In Bulletin No. 315, pp. 71–88. 1907.

Smith, G. O. Gold mining in central Washington. In Bulletin No. 213, pp. 76–80. 1903. 25c.

——— Quartz veins in Maine and Vermont. In Bulletin No. 225, pp. 81–88. 1904. 35c.

——— (See also Tower, G. W., and Smith, G. O.)

Spencer, A. C. (See Cross, Whitman, and Spencer, A. C.)

Spurr, J. E. Economic geology of the Mercur mining district, Utah. In Sixteenth Ann. Rept., pt. 2, pp. 343–455. 1895. $1.25.

——— Geology of the Aspen mining district, Colorado; with atlas. Monograph XXXI, 260 pp. 1898. $3.60.

——— The ore deposits of Monte Cristo, Washington. In Twenty-second Ann. Rept., pt. 2, pp. 777–866. 1902.

——— Ore deposits of Tonopah and neighboring districts, Nevada. In Bulletin No. 213, pp. 81–87. 1903. 25c.

——— Preliminary report on the ore deposits of Tonopah. In Bulletin No. 225, pp. 89–110. 1904. 35c.

——— Ore deposits of the Silver Creek quadrangle, Nevada. In Bulletin No. 225, pp. 111–117. 1904. 35c.

——— Notes on the geology of the Goldfields district, Nevada. In Bulletin No. 225, pp. 118–129. 1904. 35c.

——— Geology of the Tonopah mining district, Nevada. Professional Paper No. 42. 295 pp. 1905.

——— The ores of Goldfield, Nev. In Bulletin No. 260, pp. 132–139. 1905. 40c.

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SPURR, J. E. Development at Tonopah during 1904. In Bulletin No. 260, pp. 140–149. 1905. 40c.

——— Ore deposits of the Silver Peak quadrangle, Nevada. Professional Paper No. 55. 174 pp. 1906.

SPURR, J. E., and GARREY, G. H. Preliminary report on the ore deposits of the Georgetown mining district, Colorado. In Bulletin No. 260, pp. 99–120. 1905. 40c.

——— ——— The Idaho Springs mining district, Colorado. In Bulletin No. 285, pp. 35–40. 1906. 60c.

——— ——— Economic geology of the Georgetown quadrangle (together with the Empire district), Colorado, with general geology by S. H. Ball. Professional Paper No. 63. 1908.

TOWER, G. W., and SMITH, G. O. Geology and mining industry of the Tintic district, Utah. In Nineteenth Ann. Rept., pt. 3, pp. 601–767. 1899. $2.25.

WEED, W. H. Geology of the Little Belt Mountains, Montana, with notes on the mineral deposits of the Neihart, Barker, Yogo, and other districts. In Twentieth Ann. Rept., pt. 3, pp. 271–461. 1900. $1.50.

——— Gold mines of the Marysville district, Montana. In Bulletin No. 213, pp. 88–89. 1903. 25c.

——— Notes on the gold veins near Great Falls, Md. In Bulletin No. 260, pp. 128–131. 1905. 40c.

WEED, W. H., and BARRELL, J. Geology and ore deposits of the Elkhorn mining district, Jefferson County, Mont. In Twenty-second Ann. Rept., pt. 2, pp. 399–550. 1902.

WEED, W. H., and PIRSSON, L. V. Geology of the Castle Mountain mining district, Montana. Bulletin No. 139. 164 pp. 1896.

——— ——— Geology and mining resources of the Judith Mountains of Montana. In Eighteenth Ann. Rept., pt. 3, pp. 446–616. 1898. $2.15.

WEEKS, F. B. Geology and mineral resources of the Osceola mining district, White Pine County, Nev. In Bulletin No. 340, pp. 117–133. 1908.

WILLIAMS, A. Popular fallacies regarding precious-metal ore deposits. In Fourth Ann. Rept., pp. 253–271. 1884. $1.65.

WOOLSEY, L. H. Lake Fork extension of the Silverton mining area, Colorado. In Bulletin No. 315, pp. 26–30. 1907.

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COPPER.

THE YERINGTON COPPER DISTRICT, NEVADA.

By FREDERICK LESLIE RANSOME.

INTRODUCTION.

The town of Yerington is in Lyon County, in that part of western Nevada which lies between Tahoe and Walker lakes. (See fig. 6.) The nearest railway station is Wabuska, 12 miles to the north, on the Hazen-Mina branch of the Southern Pacific. The town lies in the middle of Mason Valley, through which Walker River flows northward for some 25 miles before turning east, near Wabuska, around the north end of the Walker Range on its way to Walker Lake. A small part only of its water reaches the lake, however, most of it being used for irrigating Mason Valley, which is under extensive cultivation and yields bountiful crops of alfalfa. The verdant plain, with its winding river and rows of poplars, has its beauty much enhanced by vivid contrast with the adjacent sterile ranges on the east and west, within which are the copper deposits presently to be described. Near Yerington the valley is from 3 to 4 miles wide, but it expands northward to a broad plain, in one place fully 12 miles across and irrigable only in part with the present supply of water.

The principal mines are in the mountain ridge west of town, of which the Indian name is said to be Singatse,[a] but which J. E. Spurr[b] has called the Smith Valley Range. This ridge has an average width of about 4 miles, and the general line of its crest is from 1,600 to 2,600 feet above the valley at Yerington, or from 6,000 to 7,000 feet above sea. West of Singatse Ridge is the arid northern half of Smiths Valley, sloping southward to West Walker River and containing at its upper end the Ludwig mine and the prospecting camp of Buckskin.

[a] Smith, D. T., Geology of the upper region of the main Walker River, Nevada: Bull. Dept. Geol. Univ. California, vol. 4, 1904, pp. 1–32. The name is printed Sing-ats-e in this paper.

[b] Geology of Nevada south of the fortieth parallel: Bull. U. S. Geol. Survey No. 208, 1903, p. 117.

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East of Yerington a belt of foothills, about 10 miles wide, intervenes between the valley floor and the bold Walker Range, whose steep eastern slope, probably a fault scarp, overlooks Walker Lake.

The geology of the region adjacent to Yerington received little attention from the earlier explorers. The only publication according

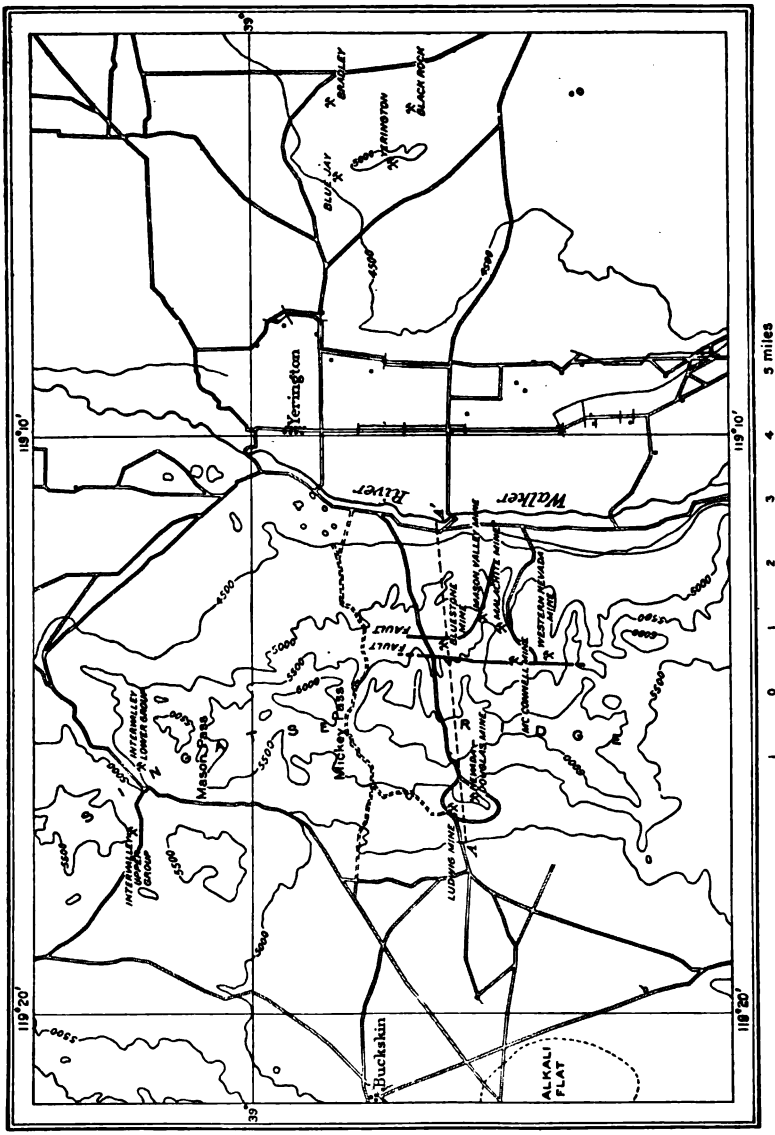

FIGURE 6.—Map of Yerington, Nev., and vicinity. *A*—*A'*, Line of section (fig. 7).

it more than incidental reference is the paper by Smith, already mentioned, which is accompanied by a geologic map based on the topography of parts of the Wabuska and Wellington atlas sheets of this Survey. Much remains to be learned regarding the distribution and

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complex structure of the rocks exposed on both sides of Mason Valley. The facts for this preliminary paper were obtained in the course of a week's visit, during which attention was directed principally to the copper deposits and to the rocks in their immediate neighborhood.

GENERAL GEOLOGY.

PRINCIPAL ROCK GROUPS.

The rocks in the Yerington district are readily divisible into two groups markedly different in age and structure. The older group consists of schists and limestone with intrusive masses of granodiorite, or quartz monzonite, and related porphyries. This assemblage of rocks was called by Smith the "bed-rock complex," a name which it is not desirable to perpetuate and which will doubtless be replaced when detailed geologic work is undertaken. The granodioritic or monzonitic rocks were by him designated "granite," "granite porphyry," and "porphyrite," although his own petrographic descriptions appear hardly to suggest these names. The younger group, called by Smith the "superjacent series," is of volcanic origin and rests with obvious unconformity upon the older complex. It may in turn be divided into two parts, namely, (1) a series of rhyolitic flows and tuffs, bedded volcanic grits, andesitic tuff, and andesitic breccia, and (2) an unconformably overlying flow of basalt.

PRE-TERTIARY ROCKS.

The schists were examined mainly on the east side of Singatse Ridge, where they are well exposed in the canyon followed by the road to the McConnell mine. (See fig. 6.) Although the schist exhibits some textural and mineralogical variations, the prevailing kind is a hard, tough dark-gray rock of dense texture. The minerals recognizable with the naked eye are triclinic feldspar, hornblende, and epidote, these being rather sparingly distributed through the finely crystalline groundmass. The microscope shows that the schist is a metamorphosed igneous rock, probably an altered andesite. The original porphyritic texture is still recognizable and some of the feldspar phenocrysts are only partly recrystallized. The femic minerals (probably augite for the most part) have been completely changed into green hornblende, epidote, quartz, and pyrite, and a fine-grained aggregate of the same secondary minerals forms the present groundmass.

The schist, which is the prevailing rock in the canyon heading near the McConnell mine, is cut by many irregular dikes of granodiorite or granodiorite porphyry and is in places stained by salts of copper. The same rock is exposed along the lower eastern slope of the ridge

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for a mile or two south of the McConnell and Western Nevada mines but is cut off ultimately by granodiorite which forms the lower part of the projecting spur on the southern border of the area mapped (fig. 6). The western slope of Singatse Ridge south of Mickey Pass is composed largely of schist similar to that described, and schist is mapped also by Smith[a] in the foothills of the Walker Range, 9 miles northeast of Yerington, but this locality was not visited.

On both slopes of Singatse Ridge masses of limestone are intricately infolded with the schist. Some of these masses are small and isolated. There is, however, one irregular but fairly continuous band of limestone that stretches north and south about halfway up the eastern slope and contains the Western Nevada, McConnell, Mason Valley, and Bluestone mines. This belt is about 1,000 feet wide at the McConnell mine and ends a few hundred yards north of the Bluestone. A similar band near the west base of the ridge contains the Ludwig and Nevada-Douglas mines.

Some of the limestone is a pure gray crystalline variety which is not noticeably metamorphosed and in which the bedding is distinct. Other parts of the formation, however, are intensely metamorphosed, containing abundant garnet, pyroxene, amphibole, epidote, and pyrite. The distribution of this metamorphism is irregular, and the gradation from masses of nearly pure garnet rock to gray limestone may be complete within a distance of a few feet. In some places the limestone has been changed to crystalline schistose aggregates, which are difficult of distinction from some of the schists not clearly derived from calcareous beds. In fact, the relation between the limestone and the andesitic schists previously described is so intimate as to leave little doubt that a series consisting originally of andesitic rocks, limestones, and perhaps some tuffs and shaly sediments has been folded, squeezed, and mineralogically changed at the same period and by the same set of metamorphic processes. The cause of the metamorphism was the intrusion of the granodiorite and closely related porphyries.

From Mickey Pass (see fig. 6) southward to the latitude of the Western Nevada mine the granodiorite occupies in general that part of the ridge which lies between the summit and the eastern belt of limestone. Along the summit the contact of the intrusive rock with the schist and limestone to the west of it is irregular, and as a whole is indefinite, as the granodiorite sends dikes into the rocks invaded by it, and includes also many masses of them. On the east, however, the line of contact between the granodiorite and the limestone of the Bluestone and Western Nevada belt is fairly straight and runs nearly north and south. It corresponds, at least in part, to a fault

[a] Op. cit., Pl. I.

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which has dropped the limestone against the intrusive rock. South of the Western Nevada mine the granodiorite appears to make up a larger part of the ridge, and at the south edge of the area included on the map (fig. 6) this rock extends practically to the river.

The granodiorite of Singatse Ridge is a rock of general granitic appearance and for the most part of evenly granular texture. The coarsest variety noted occurs southeast of the McConnell mine, the average size of the grains being here about 5 millimeters. The constituent minerals are feldspar, quartz, biotite, and hornblende, with subordinate titanite, apatite, magnetite, and zircon, and with secondary epidote. The feldspar is of at least three kinds—plagioclase, orthoclase, and microcline. The plagioclase, which in the specimens examined is near andesine in composition, appears to be generally a little more abundant than the potassium feldspars, and the rock is provisionally called granodiorite. It is quite possible, however, that thorough chemical and petrographic study would show the rock as a whole to be nearer quartz monzonite than granodiorite, the distinction between the two being often a fine one, as must happen when classificatory limits are substituted for the gradations of nature.

The low hills north of Mason Pass and along the road from the pass to Yerington are composed mainly of granodiorite porphyry, which is generally more or less altered. This rock is stained with copper salts in many places, particularly about 1½ miles west of the town, where an attempt was made some years ago to mine and smelt the copper-stained porphyry.

The prevailing rock of the hills which contain the Blue Jay, Yerington, and other mines southeast of Yerington (see fig. 6) is granodiorite, or quartz monzonite, similar in texture to that of Singatse Ridge, but generally fresher and darker. Microscopically this difference is associated with more abundant and fresher biotite than in the granodiorite west of the river, and with the presence of a nearly colorless augite intergrown with the hornblende. A rock apparently identical with the one just described forms a considerable part of the main Walker Range east of Yerington, and is the general country rock in the vicinity of the new mining districts—Mountain View, about 15 miles east of Yerington, on the west slope of the range near its crest, and Granite, about 1½ miles farther east, on the versant toward Walker Lake.

That not all of the granodiorite and granodiorite porphyry was intruded simultaneously is clearly shown in the hills southeast of Yerington, where the main mass of granodiorite is cut by porphyry dikes of similar chemical and mineralogical character. It is very likely that detailed work on Singatse Ridge would also show two or more periods of intrusion by magmas differing slightly in composition.

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The age of the schist and limestone near Yerington is not definitely known. The nearest limestone shown on Spurr's reconnaissance map[a] is in the Pine Mountain Range, 15 miles northwest of Yerington, and has yielded Triassic fossils.[b] D. T. Smith[c] found in one of the Tertiary beds a pebble which contained a fossil, probably *Daonella*, according to Prof. J. P. Smith, who, in communicating this determination to Mr. Smith, mentions having somewhere seen other Triassic fossils collected near Wabuska. The probabilities are, therefore, that the pre-Tertiary rocks near Yerington are Triassic. The intrusion of granodiorite which effected their metamorphism is supposed to have taken place in late Jurassic or early Cretaceous time. A long interval of erosion separated this event from the outbreak of Tertiary volcanism recorded by the rocks next to be described.

TERTIARY ROCKS.

The Tertiary lavas and associated sediments are younger than the ores, and no special study was made of them in the short time available for reconnaissance. East of the Bluestone mine and north of the Mason Valley mine there is a cove or depression in the east face of Singatse Ridge characterized, as may be seen from figure 6, by a rather irregular, finely cut topography, which contrasts with the bolder and steeper spurs of the main ridge. This depression is occupied by Tertiary rocks that evidently have been faulted down into the older series. The course of this fault, which is curved, is partly shown in figure 6. It was not examined north of the Bluestone mine, but the down-faulted block of volcanic rocks appeared to narrow rapidly in that direction. The fault plane is exposed in the main tunnel of the Bluestone mine, about 190 feet from its mouth, where it dips 65° E. The foot wall is limestone. Near the Mason Valley mine the fault curves eastward and can readily be traced over the surface, the ends of the various Tertiary formations abutting sharply against the older schist and limestone.

The Tertiary beds and flows in the down-faulted block strike nearly north and south. They dip to the west—that is, toward the fault at the Bluestone mine—at an angle of 45°. The base of the series may be seen on the edge of the valley near the mouth of the ravine that heads at the Mason Valley mine. At this locality a thin flow of rhyolitic glass rests on the schist with a dip of about 15° W. It is overlain by a thick flow, or series of flows, of yellowish rusty rhyolite. Near the Bluestone mine what appears to be the same

[a] Geology of Nevada south of the fortieth parallel: Bull. U. S. Geol. Survey No. 208, 1903, Pl. I.

[b] Spurr, J. E., op. cit., pp. 122–123.

[c] Op. cit., p. 9.

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rhyolite is overlain by rhyolitic tuff containing many fragments of andesite. This in turn is overlain by a very coarse andesite breccia, which is succeeded by well-bedded volcanic grits. Overlying the grits is a soft andesitic tuff.

The general relation of these Tertiary formations to the older rocks and to the structure of the ridge as a whole is illustrated in figure 7, which is partly diagrammatic and makes no pretense of refined accuracy. No measurements were made, but the total thickness of the Tertiary formations in the fault block described is estimated at over 1,500 feet.

Rhyolite, probably equivalent to that of the section just described, makes up a large part of Singatse Ridge north of Mickey Pass and, as indicated by Mr. Smith's map, is well distributed over a region considerably larger than the area here considered.

South of the McConnell mine several of the spurs and summits of Singatse Ridge are capped by olivine basalt. These remnants occur at various elevations, ranging from 4,500 to 6,500 feet. They rest generally on the granodiorite, schist, or limestone, and this fact suggests that the older Tertiary rocks were deformed and much eroded before the basaltic eruptions began. Although the basalt has probably been faulted and in places may have been gently tilted, it nowhere shows dips as high as those of the rhyolitic and andesitic rocks.

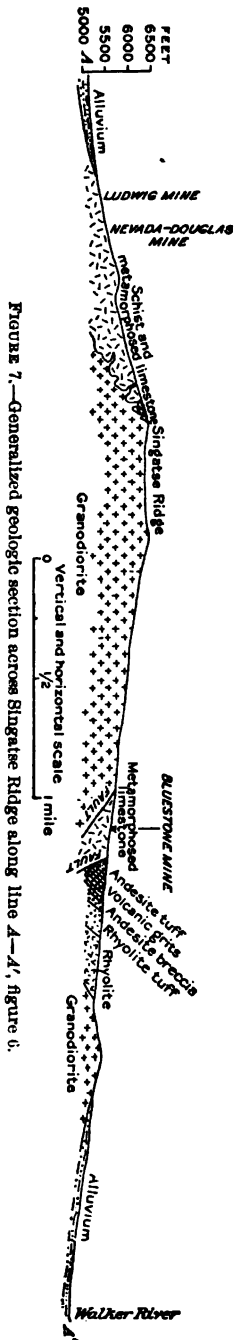

FIGURE 7.—Generalized geologic section across Singatse Ridge along line A—A', figure 6.

DISTRIBUTION OF THE MINES.

The general distribution of the important mines and prospects near Yerington may be seen from figure 6. One group, the members of which are similar in the character and geologic relations of their ore bodies, lies on the east slope of Singatse Ridge southwest of Yerington, about halfway from valley to crest. Together they constitute a chain 2 miles in length, the mines from north to south being the Bluestone, Mason Valley, Malachite, McConnell, and Western Nevada. Most of these mines have shipped some oxidized copper ore, but operations at present are confined to development in the sulphide zone or, at the Mason Valley mine, in a zone of mixed oxidized and sulphide ore.

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These mines are from 4 to 8 miles from Yerington by wagon road. The history of all goes back thirty years or more, but none has produced abundantly or continuously. At the western foot of Singatse Ridge are the Nevada-Douglas and Ludwig mines, now under one ownership, the Nevada-Douglas Company having bought the Ludwig in 1907 for about $500,000. By the direct but steep road over the ridge past the Bluestone mine the distance from Yerington to these mines is about 7 miles. The Mason Pass road from town to the Ludwig mine is about twice as long, but is much used because of its better gradient. Both the Nevada-Douglas and Ludwig are old mines and have intermittently produced considerable ore; how much is not known. The Ludwig ore has of late been hauled by a traction engine to Wabuska.

About a mile north of Mason Pass (see fig. 6) and 9 miles northwest of Yerington by road, are the upper and lower workings of the Intervalley mine. These are shallow prospects which were never productive and are now idle. Buckskin, about 4½ miles west-northwest of the Ludwig mine, is a prospecting camp, in the vicinity of which some shallow exploration is in progress.

Another group of prospects lies in the low hills from 4 to 5 miles southeast of Yerington. Among these the Blue Jay, with a 450-foot shaft, and the Yerington, 412 feet deep, are the most important. The latter only was in operation in 1908. A mile east of the Blue Jay is the Bradley, about 100 feet deep, and a mile south of this mine is the Black Rock, with still less development. No work was in progress at either place at the time of visit.

DESCRIPTIONS OF MINES AND PROSPECTS.

BLUESTONE MINE.

The Bluestone mine is situated 4 miles southwest of Yerington, halfway up the east slope of Singatse Ridge, at an elevation of about 5,300 feet. It was worked about thirty years ago, and for a time supplied natural bluestone (chalcanthite) to the amalgamating mills at Virginia City. A small smelter was built at the mine and ran for a few years on partly oxidized ore stoped above the 100-foot level; but no great production was attained and operations of late have been restricted to systematic exploration and to experiments in ore treatment.

The mine is opened on three levels, approximately 100, 200, and 275 feet below the surface. There is also a sublevel 25 feet below the 275-foot level. The principal drifts and crosscuts are within the ore body, which is of generally elliptical plan with a length between 300 and 400 feet and a width between 200 and 300 feet. No regular structures are followed by the drifts, which are devious and have been

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so laid out as to leave no large blocks of the ore-bearing ground unexplored. The 100-foot and 300-foot levels connect with the surface through adits. The lower or main adit runs westward and cuts the ore body at 780 feet from the portal. It then turns toward the northwest and continues for nearly 400 feet through the ore and into the country rock on the other side. The total development work is from 6,000 to 8,000 linear feet.

The ore lies in limestone near the contact of this rock with granodiorite, which is widely exposed just west of the mine. The contact, as mentioned on page 102, is due to faulting; the fissure at this place strikes a few degrees east of north and dips 35° E. Both granodiorite and limestone are crushed and sheared in its vicinity. The ore is wholly in the limestone, being from 50 to 100 feet or more east of the fault zone, which shows no mineralization. The belt of limestone containing the ore is here about 700 feet wide and is bounded on the east by the down-faulted block of Tertiary volcanic rocks already described. This fault, crossed by the main adit 190 feet from the portal, is a clean-cut unmineralized fissure with an easterly dip of 65°. It has no connection whatever with the deposition of the ore.

The plan of the ore body, as already stated, is roughly elliptical, the longer axis trending about 25° west of north. The northwest end of the mass is thus nearer the granodiorite than the southeast end. The dip is variable, but the mass as a whole dips to the east at an angle of about 45°, so that the ore is nearer the granodiorite on the 275-foot than on the 100-foot level. There is no sharp separation between ore and limestone, although on the foot-wall side of the ore body there is a persistent seam or fissure which in places serves practically as a wall. The ore, however, does not everywhere extend as far west as the seam, and the limestone beyond this fissure, which shows no evidence of important movement, contains the same minerals as the ore. A similar but less persistent fissure serves in some places as a hanging wall for the ore body, which at its ends passes gradually into mineralized but unprofitable limestone. Similar gradations from ore to limestone may be observed at many places within the mass of the ore body. The ore maintains its general character down to the 275-foot level, but the 300-foot sublevel at the time of visit showed only mineralized country rock. Mr. C. A. Weck, superintendent of the mine, has estimated on the basis of careful sampling that the quantity of ore blocked out is between 2,000,000 and 3,000,000 tons, with an average tenor of 3 per cent of copper.

The ore consists essentially of chalcopyrite disseminated as grains and small irregular masses through limestone that has been altered to an aggregate consisting chiefly of a yellowish-gray epidote with subordinate calcite and quartz. A little garnet has been noted by

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Mr. Weck, and a careful microscopical study of various specimens of the metamorphosed limestone in the vicinity of the ore body would probably reveal other silicates also. The mass of the ore, however, has the simple mineralogical composition given above. The ore proper is almost free from pyrite, but the chalcopyrite gives place to this sulphide as the ore grades into country rock. The microscope shows a little apatite with the epidote in some thin sections.

Oxidation is not extensive and scarcely penetrates to the 100-foot level, while chalcopyrite is present in the croppings. The products of oxidation are malachite (with possibly some brochantite and libethenite), azurite, cuprite, and chalcanthite. These are generally associated with sulphides, and there are no large masses of thoroughly oxidized ore. A little chalcocite occurs above the 100-foot level, but there has been no important enrichment through the secondary formation of this mineral. It is evident that the ore body as a whole is too solid to have been penetrable to any considerable depth by oxidizing solutions, and that erosion has kept pace with the process of weathering.

At the time of visit experiments were in progress to determine the best method of concentrating the ore. The scheme devised is to crush the ore and pass it through a 10-mesh screen. The material is then given a slight roasting, which renders the chalcopyrite magnetic, and is passed through Wetherill magnetic separators. The experimental extraction ranges from 92 to 95 per cent, but the concentrates still contain considerable epidote.

The Bluestone ore body is a partial replacement of limestone by chalcopyrite, this replacement being accompanied by metamorphism of the limestone to epidote and other silicates, and by the metasomatic formation of disseminated pyrite. The process of ore deposition appears to have been completed before the limestone was faulted down into its present relation with the granodiorite and, of course, before the faulting which affected the Tertiary volcanic rocks. Ore deposition bears no genetic relation to any discoverable zone of major fissuring. The original cupriferous solutions probably penetrated the limestone at high temperature and under great pressure through small or microscopic fractures. The mineralogical character of the deposits suggests that the deposition of the ore was closely connected with the intrusion of the granodiorite, and that the ore body should be classified with those of contact-metamorphic origin.

MASON VALLEY MINE.

The Mason Valley mine is three-quarters of a mile southeast of the Bluestone and at nearly the same elevation. The ore body outcrops at about 5,500 feet above sea level, and has been cut by tunnels running southwestward into the ridge at elevations of 5,385, 5,325, and

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5,200 feet. A new tunnel, known as No. 4, is being driven at 5,080 feet, and is expected to enter the ore at about 1,100 feet from the portal. There are also some abandoned workings, which attained a depth of nearly 200 feet, and which, like the Bluestone mine, supplied copper sulphate to the mills on the Comstock lode. The recent work is of an exploratory character, and is mainly on the No. 3 level.

The country rock of the ore is limestone, which shows much local alteration. This rock is cut off just north of the mine by the fault previously mentioned, which has dropped the Tertiary volcanic rocks against it. Whether the limestone is entirely continuous along the west side of this fault with that of the Bluestone mine, or whether some exposures of schist intervene, was not ascertained. The limestone area continues to the south over the spur between the Mason Valley and Malachite mines, both of these being on the same irregular zone of mineralization. Some schist, however, separates this belt from the limestone of the McConnell mine. (See fig. 6.) The Mason Valley mine is at least half a mile east of the fault contact of the limestone with the granodiorite.

As exposed at the surface the copper-bearing zone in the limestone trends nearly north and south, but is curved and irregular. Its greatest width is about 150 feet. Its total length, without measurement of sinuosities, is nearly 2,000 feet. Probably beneath a small part only of the copper-stained croppings is ore present in commercial quantity. The workings of the Mason Valley mine show that the ore bodies are irregular and indefinitely bounded masses which, as a rule, grade into garnetized limestone, although in some places, particularly on the west side, there is a close fissure or joint separating ore from country rock. The development at present is insufficient to reveal the sizes or shapes of the ore shoots, but apparently they do not extend continuously from the surface down. The No. 2 tunnel, for example, is in barren ground, with ore above and below it.

The sulphide ore is composed essentially of pyrite and chalcopyrite, with garnet, pyroxene, and a little calcite. Epidote is possibly present in some varieties, but does not appear in the thin sections examined. The most abundant and characteristic gangue mineral is a pale-brown or amber-tinted garnet, which in crystals is almost transparent, and where massive is not unlike the epidote rock of the Bluestone mine in general appearance. No chemical analysis has been made of this garnet. Although its color suggests the calcic aluminous variety grossularite, the work of Lindgren [a] and of Kemp and Gunther [b] has shown that much of the brown garnet in contact-

[a] Copper deposits of the Clifton-Morenci district, Arizona: Prof. Paper U. S. Geol. Survey No. 43, 1905, p. 134.

[b] White Knob copper deposits, Mackay, Idaho: Trans. Am. Inst. Min. Eng., vol. 38, 1908, pp. 286–287.

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metamorphic deposits is the calcic-ferric variety andradite, or is a kind containing at least a considerable proportion of the andradite molecule. Under the microscope some of the garnet from the Mason Valley mine shows the optical anomaly frequently seen in this mineral, namely, sharp division into birefringent sectors.

The pyroxene is light green and in thin section is nearly colorless. It is without crystal planes and either occurs in xenomorphic aggregation with garnet and sulphides or forms dull-green radiating lamellar masses of diallagic habit. The lack of luster and transparency of these masses suggests partial decomposition, and microscopical examination shows this to be the case; all the coarse lamellar aggregates examined are mixtures of original pyroxene with secondary serpentine, calcite, fibrous amphibole, and in some specimens epidote. The pyroxene is presumably diopside or an augite near diopside in composition.

The primary ore of the Mason Valley mine contains more pyrite with the chalcopyrite than that of the Bluestone mine, and appears to be generally of lower grade. Oxidation, however, has penetrated deeper and has effected some local concentration down to the No. 3 tunnel, although some sulphides occur at the surface. On the No. 3 level there is a considerable body of rich ore, consisting of impure earthy cuprite with much disseminated native copper. The shape and extent of this body, which contains up to 20 per cent of copper, have not been fully ascertained. Chalcocite in a soft sooty condition occurs sparingly, but there has been no important enrichment through the formation of this sulphide. The minerals noted in the oxidized zone are malachite, azurite, cuprite, native copper, limonite, gypsum, and chalcanthite.

As in the Bluestone mine, the original ore of the Mason Valley mine forms irregular metasomatic masses in limestone and is without definite boundaries. Its character suggests contact-metamorphic action, although the ore is not at present close to the granodiorite.

MALACHITE MINE.

The Malachite mine is from a third to half a mile south of the Mason Valley mine and is on the same general zone of mineralization. The workings comprise some old adits from which was taken partly oxidized ore similar to that of the Mason Valley mine. At the time of visit a shaft was being put down in the limestone below the old tunnels, but this shaft was not yet in ore and was not examined.

McCONNELL MINE.

The McConnell mine is about a mile southwest of the Mason Valley mine and 7 miles from Yerington by road. The limestone, which is the mineralized rock, here constitutes a north-south belt from 300 to

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400 yards wide, bounded on the east by schist and on the west by granodiorite. Whether this western contact is the result of intrusion or of faulting is not quite clear, but it is thought to correspond to a fault. The ore bodies are at the western edge of the belt near the granodiorite. The limestone which incloses them is a fine-grained gray variety which is not on the whole much altered, although here and there it contains irregular masses of silicates and sulphides. Between this gray limestone and the granodiorite intervenes locally a small mass of intensely metamorphosed rocks that are cut by dikes and tongues of granodiorite. These altered beds, probably once calcareous shales, are now crystalline schists rich in garnet and epidote.

The older workings of the McConnell mine comprise open cuts and short tunnels in the oxidized ore and an adit several hundred feet in length with considerable drifting in the sulphide zone. At the time of visit work was confined to sinking by a shaft near the portal of the main adit. This shaft was then 400 feet deep in dark limestone carrying a little pyrite and epidote.

The unoxidized ore, as exposed in the lower or main adit, resembles in appearance that of the Mason Valley mine. There is much pyrite with the chalcopyrite, and the material is evidently not of high grade. The principal gangue minerals are pale-brown garnet and a light-green amphibole. It is probable that pyroxene is also present in some parts of the ore body, although it does not appear in the thin sections examined. Coarse lamellar aggregates similar to those in the Mason Valley mine, but more decomposed, were noted in some of the cuts in the partly oxidized ore.

WESTERN NEVADA MINE.

The Western Nevada mine is half a mile south of the McConnell mine and is similarly situated on the same limestone belt. The zone of mineralization is here about a quarter of a mile wide, with irregular isolated bodies of sulphides and silicates distributed erratically through it. Some of these bodies are at or very close to the granodiorite; others are separated from it by masses of gray unaltered limestone. The body of ore now being explored in the Western Nevada mine is about 1,000 feet east of the granodiorite, the intervening rock, which forms a small hill, being comparatively little-altered gray limestone.

The principal adit is 1,000 feet in length and runs northeastward through the limestone to the granodiorite. There are extensive lateral drifts from this adit, and a winze, 90 feet deep at the time of visit, will be sunk to 300 feet. The present workings explore the ore bodies to a total depth of about 300 feet.

The contact between the limestone and granodiorite is due to faulting, the fault plane dipping to the east at 54°. There is a seam

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of gouge, and the limestone of the hanging wall is much broken but no mineralization has taken place along the fault. About 100 feet east of the fault fissure is a nearly north-south zone of crushing in the limestone, which is occupied in part by a quartz vein carrying pyrite but no constituents of value. This vein, which has not been much explored, dips 35° E. It is probably younger than the cupriferous ore bodies in the limestone, but its age could not be definitely ascertained.

The croppings of the Western Nevada mine, which are partly capped by younger basalt, show abundant chrysocolla, copper carbonates, and epidote, and considerable bodies of such ore have been opened in cuts and superficial tunnels. The main adit that passes under these older workings has not, however, revealed as much ore as was hoped. It traverses for the most part hard altered limestone with irregular and ill-defined bunches of lean pyritic ore. The change from masses of sulphides and metamorphic silicates to fine granular white or gray limestone is in many places unexpectedly abrupt. The most altered variety is a hard, tough dark-green aggregate of pale-green augite or diopside, garnet, pyrite, and chalcopyrite.

In some places the garnet has decomposed to chlorite and the augite to pale-green amphibole, serpentine, and calcite. Calcite occurs also in some specimens as a constituent belonging, like the garnet and pyroxene, to the period of metamorphism.

The ore bodies of the Western Nevada mine as opened on the main level at a depth of about 200 feet have the general character of unenriched contact-metamorphic deposits. Their profitable exploitation and concentration constitute a difficult problem.

LUDWIG MINE.

The Ludwig mine lies on the west side of Singatse Ridge at the edge of Smiths Valley. It is worked through a vertical shaft 400 feet deep with a steeply inclined winze 200 feet deep, below the 400-foot level. The 400-foot, 500-foot, 550-foot, and 600-foot levels were the only ones examined, the levels above the 400-foot having been stoped out and abandoned. The drifts vary in direction from north to N. 35° E. The most extensive level is about 400 feet long.

Unlike the deposits on the east side of the main ridge, the Ludwig ore body is of lodelike form with a steep dip to the east. The ore zone is from 50 to 60 feet wide on the upper levels, but in the deeper workings the number of crosscuts is too small to show fully the limits of the pay shoots. No walls are known, for example, on the 400-foot level. The general country rock is limestone. That in the foot wall is an ordinary gray massive limestone which for a depth of 50 feet

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has been extensively altered to solid alabastine gypsum by acid solutions from the oxidizing sulphides. The hanging-wall limestone is generally thin bedded and contains garnet with other metamorphic silicates. The beds dip to the east at about 65°, but are intruded and disturbed by dikes of granodiorite porphyry, one of which, just north of the shaft, forms the hanging wall of the lode. Within the ground explored the fissuring that permitted the ore deposition appears to have coincided with the plane of bedding between the massive limestone, which is probably over 100 feet thick, and the thinner, more metamorphosed beds now forming the hanging wall.

The ore from the surface to the 500-foot level is mainly oxidized. It consists on the 400-foot level of a large mass of shattered limestone, whose interstices and fissures are filled with coarsely crystalline calcite. This vein matter once contained sulphides, but these have been oxidized, and chrysocolla, earthy oxides, and carbonates have been secondarily concentrated in solution cavities and along zones of crushing in the original vein material. The best oxidized ore thus forms bunches distributed through the lode. There was considerable migration of the copper during oxidation and the chrysocolla and carbonates have been in part deposited by metamorphism in the calcite, the replacement having begun its attack from cracks and cleavage planes. Some unoxidized ore, consisting of pyrite and chalcopyrite in a gangue of calcite, pale-brown garnet, and quartz, remains at the south end of the 400-foot level and shows what must have been the character of at least a part of the mass that has undergone oxidation.

The ore on the 550-foot level consists chiefly of sulphides and carries from 2 to 3 per cent of copper. There is, however, some rich oxidized ore even at this depth, one soft, earthy face exposed at the time of visit affording assays up to 40 per cent of copper. Ore enriched by the deposition of chalcocite on pyrite is also present, but the quantity of such rich sulphides is apparently not great. The 600-foot level showed no ore at the time of visit; the vein filling then exposed consisted of coarsely crystalline white calcite with some quartz and a little pyrite.

A notable feature of the oxidized ore is the occurrence here and there of libethenite, a hydrous phosphate of copper ($Cu_3P_2O_8 \cdot Cu(OH)_2$), in crystalline aggregates resembling malachite. Attention was first called to the occurrence of this mineral in the Yerington district by Smith,[a] who found at the Blue Jay mine, east of town, a few small crystals, which were studied crystallographically in the Survey laboratory by Mr. W. T. Schaller.[b]

[a] Op. cit., p. 31.

[b] Clarke, F. W., and others, Contributions to mineralogy; Bull. U. S. Geol. Survey No. 262, 1905, pp. 140–143.

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The Ludwig deposit differs from those on the east side of the ridge in the fact that it fills a fissure. The original filling contains some garnet and quartz, but is predominantly calcite, with enough pyrite and chalcopyrite to make an ore of very low grade.

On the hill slope above the Ludwig mine there are many places where the schist and metamorphosed limestone, particularly the latter, carry small quantities of oxidized copper ore. Most of these deposits are clearly small bunches. Some of them probably represent sulphides that have been oxidized in place; others appear to be due to secondary deposition along minor fissures by cupriferous solutions which have percolated down from inconsiderable masses in rock that has since been removed by erosion.

NEVADA-DOUGLAS MINE.

The old workings of the Nevada-Douglas mine, idle at the time of visit, are, as shown in figure 6, on the crest of a little spur, half a mile southeast of the Ludwig mine and 500 feet above the valley. The country rock is limestone, which is extensively but irregularly altered to garnet rock. At the mine the garnet zone is at least 600 feet wide, strikes north and south, and carries bunches of ore that have no definite walls, although they trend in general with the inclosing rocks. The old workings, which are fairly extensive, consist of various tunnels, shafts, and open cuts that are not all on the same ore body.

Most of the ore taken out and piled on the dumps is oxidized material and consists largely of blue and green chrysocolla. Associated with this mineral is some epidote in coarsely crystalline masses and small quantities of copper carbonates. The oxidized ores are succeeded at moderate depth by fine-grained granular masses of pyrite, chalcopyrite, and garnet. This material has undergone some enrichment by the deposition of a dark copper sulphide, probably chalcocite, on the surfaces and in cracks of the older sulphides.

At the edge of Smiths Valley, west of the old workings and 2,200 feet south of the Ludwig mine, a new tunnel has been begun for the purpose of cutting the Nevada-Douglas ore bodies at greater depth. This tunnel was about 400 feet long at the time of visit and is practically all in garnetized limestone. No work was in progress at this adit in 1908.

INTERVALLEY MINE.

The Intervalley workings lie about a mile north of Mason Pass and are in two groups a mile apart. The openings are shallow and no work was in progress in 1908. The country rock is granodiorite porphyry. The main workings of the upper group, which were the only ones examined, consist of an incline about 100 feet in length

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with some short drifts. The deposit is a vein which strikes nearly east and west and at the surface has a width of 3 to 4 feet. The filling is calcite with some malachite and chrysocolla. The dip is to the north and is about 12° at the surface, but increases to 30° or 35° near the bottom of the incline. The vein appears to have little persistency in any direction and at the face of the incline is a mere seam with no ore.

YERINGTON MINE.

The property of the Yerington Copper Company was the only one in the group east of town at which any prospecting was in progress in 1908. The general country rock is granodiorite or quartz monzonite, which is cut by a dike of porphyry about 25 feet wide. The dike strikes N. 55° W. and dips 65° to 70° SE. The shaft, which is 412 feet deep, follows the mineralized foot wall of this dike.

The dike rock is apparently granodioritic or monzonitic, but it is altered and contains much epidote, calcite, chlorite, and sericite. Quartz is less abundant than in the granodiorite which the dike cuts. The dike becomes finer grained near its walls and grades into a banded flinty selvage which, near the surface, is generally stained with carbonate of copper.

The ore, as seen on the 400-foot level, consists essentially of pyrite, which is disseminated through the granodiorite for a distance of a few feet from the dike. No distinctly cupriferous minerals were seen at this depth and the ore is clearly of very low grade. Its average width appeared to be about 4 feet. A little good chalcocite ore was found between this lean ore and the oxidized zone. There is no fissure filling and no evidence of much movement in the rocks since the intrusion of the dike. Mineralization has worked metasomatically outward from the contact between the dike and its inclosing rock, producing a low-grade pyritic deposit which has been superficially enriched by descending solutions.

The dike and its attendant zone of mineralization extend northeastward over the ridge (see fig. 6) for a distance of at least half a mile, and have been superficially prospected at various places.

BLUE JAY MINE.

A mile north of the Yerington mine, on the same side of the ridge, is the Blue Jay mine, in a band of dark rock which is distinctly visible from town and was supposed in the field to be a dike cutting the granodiorite. On fresh fracture and in thin section, however, the difference between the rocks proves to be slight and to be partly due to the greater alteration of the supposed dike. The dark rock, therefore, may be merely a zone of alteration accompanying two or more parallel fissures. The necessarily brief examination given this fea-

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ture and the few specimens collected are insufficient to determine the point, and pending further examination the darker rock will be provisionally referred to as a dike.

The dike is from 300 to 400 feet wide at the Blue Jay mine, strikes N. 70° E., and can be followed in that direction for about a mile. It becomes narrower toward the east and finally disappears under alluvium. It is stained with copper salts at many places along its course, and near the Blue Jay mine bunches of oxidized copper ore are distributed through the entire width of the dike. The principal mineralization, however, follows the southern wall, on which a shaft has been sunk for 450 feet. The contact is said to be vertical for about 150 feet and then to dip steeply to the north. The dump of the abandoned shaft shows considerable oxidized ore containing chrysocolla, malachite, cuprite, and libethenite. Careful study might show also some brochantite, a mineral not readily distinguishable from malachite on superficial examination. The oxidized ore passed below into lean pyritic ore with some chalcopyrite. Whether any chalcocite was found is not known.

The material on the dump indicates that the deposit is of metasomatic origin and does not to any considerable extent fill an open fissure.

BRADLEY PROSPECT.

The Bradley prospect is a mile east of the Blue Jay mine, on a fissure in granodiorite. The fissure strikes N. 35° E. and dips 40° SE. The workings comprise an inclined shaft 100 feet deep and some open cuts. Only oxidized ore was seen. It occurs in bunches along the fissure zone, the maximum width observed in the accessible opening being about 4 feet. The ore contains some specularite.

BLACK ROCK PROSPECT.

The Black Rock prospect is a little more than a mile south of the Bradley and is even less developed. The fissure, along which the granodiorite has been mineralized, strikes N. 70° E. and dips 60° N. The material thrown out from the shallow openings contains considerable vein quartz, showing that the deposit has, in part at least, filled open spaces in the fissure. This quartz carries much specularite with a little chrysocolla and chalcopyrite. The specularite is apparently not due to superficial oxidation, but has crystallized with the quartz.

GENERAL CHARACTERIZATION OF THE COPPER DEPOSITS.

As appears from the preceding descriptions, the copper deposits near Yerington are of three kinds—(1) irregular bodies formed by metasomatic replacement of limestone and genetically associated with

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metamorphism of a kind usually attributed to the contact action of intrusive rock, (2) metasomatic vein deposits in altered limestone, and (3) metasomatic vein deposits in granodiorite.

The deposits of the first class are exemplified by those of the Bluestone, Mason Valley, Malachite, McConnell, Western Nevada, and Nevada-Douglas mines. The original sulphides of these ores are pyrite and chalcopyrite in various proportions. The gangue minerals are pyroxene, amphibole, epidote, garnet, and calcite. The proportions of these also vary widely in different deposits. The tenor of these primary ores is generally low; probably no masses of large size average over 3 per cent in copper. The largest and richest body of such ore that has been at all satisfactorily blocked out is that of the Bluestone mine, which is about 300 feet long and of approximately the same width and depth.

The oxidation of these ore bodies has not been extensive and appears to have penetrated deepest in the Mason Valley mine. There has been no important enrichment through the deposition of chalcocite or other secondary sulphides, though some of the oxidized ore is of high grade.

Although these deposits are of a character usually associated with contact metamorphism they are not very closely related to igneous contacts. Those nearest the granodiorite owe their present proximity to that rock to faulting. Consequently they can not be regarded as typical contact-metamorphic deposits, although they are believed to belong in that general class and to be genetically connected with the granodioritic intrusion.

The only important deposit of the second class is the Ludwig ore body, in which the vein is composed mainly of coarsely crystalline calcite carrying some garnet with pyrite and chalcopyrite. Oxidation in this deposit has extended to a depth of about 500 feet and has produced ore of shipping grade. At the base of the oxidized zone there has been some chalcocitic enrichment. The occurrence of garnet in the vein material links this deposit with those of the first group, but the fissuring and veining probably took place after the limestone had been considerably metamorphosed.

The deposits of the third class include those of the Intervalley, Blue Jay, Yerington, Bradley, and Black Rock mines or prospects. They are characterized by the development of pyrite with subordinate chalcopyrite in granodiorite or monzonite along zones of fissuring. In two of them, the Intervalley and Black Rock, there has been some filling of open spaces, but in the others the sulphides have developed within the rock alongside the narrow fissures that served as channels for the depositing solutions. No thorough study of the action of these solutions on the wall rock has been made. The deposits, however, are believed to represent a stage of mineralization

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later than those in which the deposits of the first and second classes were formed. The economic importance of the deposits of the third class is as yet unproved.

The total quantity of oxidized ore exposed in the district is small and there is no indication of any extensive sulphide enrichment. The quantity of gold or silver in the ores is practically negligible. The future of the mines depends on the working of low-grade primary deposits. The conditions are in some respects favorable for cheap mining and concentrating; a railroad could be constructed from Wabuska along Walker River with very little difficulty, water is more plentiful than in most other parts of Nevada, and many agricultural products can be grown in Mason Valley. On the other hand, water, tailings, and smelter fumes are subjects concerning which miners and farmers usually find agreement difficult.

MOUNTAIN VIEW AND GRANITE.

Although the settlements of Mountain View and Granite are not in the Yerington district, they were hastily visited in the course of the reconnaissance, and such observations as were made may conveniently be recorded in this place. Mountain View is 15 miles east of Yerington, near the crest of the Walker Range. The general country rock is granodiorite or quartz monzonite, which is overlapped by rhyolite along the west side of the range. Both andesite and rhyolite occur on the crest of the range south of Mountain View, resting on the granodiorite and capped by basalt.

The Mountain View mine is developed by three short tunnels. The lode, which follows a narrow decomposed dioritic dike, strikes N. 75° E., and is about vertical. The mineralization is mainly on the south side of the dike, and much of the vein filling is a soft, light pumice-like quartz that contains a little native sulphur. This material has probably resulted from the oxidation of a pyritic vein. It is said to carry up to $50 a ton in gold and silver. The lower tunnel at the time of visit was just getting into pyrite, the tenor of which was not known. But little vein quartz was visible on this level, the pyrite being disseminated through the dike accompanied by a few small bunches of specularite.

The same dike and attendant fissures continue eastward over the crest of the range, and on the east slope, near the summit, were being worked by lessees on the Big Twenty ground. Here there were three or four shafts up to 100 feet deep. A little oxidized gold ore had been shipped, but the lessees had not received returns at the time of visit and did not know its tenor.

East of these leases and about 1½ miles east of Mountain View is Granite, a new town of 30 or 40 tents and board cabins. This set-

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tlement, which is most easily reached from Schurz, on the Hazen-Mina branch of the Southern Pacific Railroad, was not very active at the time of visit and prospecting appeared to be in progress only along the line of the Mountain View and Big Twenty lode and at the Beach copper mine, about 1½ miles south of town and near the crest of the range. At this place there is a prominent vein in granodiorite, which strikes N. 50° E. and dips 60° SE. This vein is from 8 to 25 feet wide at the surface and shows copper carbonates in a gangue of quartz and crushed granodiorite. A tunnel 400 feet in length has been run from 100 to 200 feet below the croppings and shows that the granodiorite is considerably disturbed and that the vein, so large above, has a tendency to split up and become irregular below. No ore had been found on this level at the time of visit, but work was still in progress.

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SURVEY PUBLICATIONS ON COPPER.

The following list includes the principal publications on copper by the United States Geological Survey or by members of its staff. In addition to the publications cited below, certain of the geologic folios listed in the "Introduction" contain discussions of the copper resources of the districts of which they treat.

The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Those marked "Exhausted" are not available for distribution, but may be seen at the larger libraries of the country.

BAIN, H. F., and ULRICH, E. O. The copper deposits of Missouri. In Bulletin No. 260, pp. 233–235. 1905. 40c.

BALL, S. H. Copper deposits of the Hartville uplift, Wyoming. In Bulletin No. 315, pp. 93–107. 1907.

BOUTWELL, J. M. Ore deposits of Bingham, Utah. In Bulletin No. 213, pp. 105–122. 1903. 25c.

——— Economic geology of the Bingham mining district, Utah. Professional Paper No. 38. 413 pp. 1905.

——— Ore deposits of Bingham, Utah. In Bulletin No. 260, pp. 236–241. 1905. 40c.

CALKINS, F. C. (See Ransome, F. L., and Calkins, F. C.)

COLLIER, A. J. Ore deposits of the St. Joe River basin, Idaho. In Bulletin No. 285, pp. 129–139. 1906.

DILLER, J. S. Copper deposits of the Redding region, California. In Bulletin No. 213, pp. 123–132. 1903. 25c.

——— Mining and mineral resources in the Redding district in 1903. In Bulletin No. 225, pp. 169–179. 1904. 35c.

DOUGLAS, J. The metallurgy of copper. In Mineral Resources U. S. for 1882, pp. 257–280. 1883.

——— The cupola smelting of copper in Arizona. In Mineral Resources U. S. for 1883–84, pp. 397–410. 1885.

EMMONS, S. F. Geological distribution of the useful metals in the United States—Copper. Trans. Am. Inst. Min. Eng., vol. 22, p. 73. 1894.

——— Economic geology of the Butte (copper) district, Montana. Geologic Atlas U. S., folio No. 38. 1897.

——— Copper in the red beds of the Colorado Plateau region. In Bulletin No. 260, pp. 221–232. 1905. 40c.

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EMMONS, S. F. The Cactus copper mine, Utah. In Bulletin No. 260, pp. 242–248. 1905. 40c.

EMMONS, W. H. The Cashin mine, Montrose County, Colo. In Bulletin No. 285, pp. 125–128. 1906.

GIGNOUX, J. E. The manufacture of bluestone at the Lyon mill, Dayton, Nev. In Mineral Resources U. S. for 1882, pp. 297–305. 1883.

GORDON, C. H. Mining districts of south-central New Mexico. Bulletin No. —. (In preparation.)

GRATON, L. C. Copper. In Mineral Resources U. S. for 1906, pp. 373–438. 1907.

——— Copper. In Mineral Resources U. S. for 1907, pp. 571–644. 1908.

HEIKES, V. C. (See Weeks, F. B., and Heikes, V. C.)

HOWE, H. M. Copper smelting. Bulletin No. 26. 107 pp. 1885. Exhausted.

IRVING, R. D. The copper-bearing rocks of Lake Superior. Monograph V. 464 pp. 1883.

LINDGREN, W. The copper deposits of the "Seven Devils," Idaho. In Mining and Scientific Press, vol. 78, p. 125. 1899.

——— The copper deposits of the Seven Devils. In Twentieth Ann. Rept., pt. 3, pp. 249–253. 1900.

——— Copper deposits of Snake River and Powder River, Oregon. In Twenty-second Ann. Rept., pt. 2, pp. 554–776. 1901.

——— Copper deposits at Clifton, Ariz. In Bulletin No. 213, pp. 133–140, 1903. 25c.

——— Copper deposits of Clifton-Morenci district, Arizona. Professional Paper No. 43. 375 pp. 1905.

——— Notes on copper deposits in Chaffee, Fremont, and Jefferson counties, Colo. In Bulletin No. 340, pp. 157–174. 1908.

PETERS, E. D. The roasting of copper ores and furnace products. In Mineral Resources U. S. for 1882, pp. 280–297. 1883.

——— The mines and reduction works of Butte City, Mont. In Mineral Resources U. S. for 1883–84, pp. 374–396. 1885.

PHALEN, W. C. Copper deposits near Luray, Va. In Bulletin No. 285, pp. 140–143. 1906.

PIRSSON, L. V. (See Weed, W. H., and Pirsson, L. V.)

RANSOME, F. L. Copper deposits of Bisbee, Ariz. In Bulletin No. 213, pp. 149–157. 1903. 25c.

——— The Globe copper district, Arizona. Professional Paper No. 12. 168 pp. 1904. 70c.

——— Geology and ore deposits of the Bisbee quadrangle, Arizona. Professional Paper No. 21. 168 pp. 1904.

RANSOME, F. L., and CALKINS, F. C. The geology and ore deposits of the Cœur d'Alene district, Idaho. Professional Paper No. 62. 1908.

SPENCER, A. C. Mineral resources of the Encampment copper region, Wyoming. In Bulletin No. 213, pp. 158–162. 1903. 25c.

——— Reconnaissance examination of the copper deposits at Pearl, Colo. In Bulletin No. 213, pp. 163–169. 1903. 25c.

——— Copper deposits of the Encampment district, Wyoming. Professional Paper No. 25. 107 pp. 1904. 15c.

ULRICH, E. O. (See Bain, H. F., and Ulrich, E. O.)

VAUGHAN, T. W. The copper mines of Santa Clara Province, Cuba. In Eng. and Min. Jour., vol. 72, pp. 814–816. 1901.

WATSON, T. L. Notes on the Seminole copper deposits of Georgia. In Bulletin No. 225, pp. 182–186. 35c.

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WEED, W. H. Types of copper deposits in the southern United States. In Trans. Am. Inst. Min. Eng., vol. 30, pp. 449–504. 1901.

——— Copper mines of Las Vegas, Chihuahua, Mexico. In Trans. Am. Inst. Min. Eng., vol. 32, pp. 402–404. 1902.

——— Copper deposits near Jimenez, Chihuahua, Mexico. In Trans. Am. Inst. Min. Eng., vol. 32, pp. 404–405. 1902.

——— Copper deposits of Cananea, Sonora, Mexico. In Trans. Am. Inst. Min. Eng., vol. 32, pp. 428–435. 1902.

——— Ore deposits at Butte, Mont. In Bulletin No. 213, pp. 170–180. 1903. 25c.

——— Copper deposits of the Appalachian States. In Bulletin No. 213, pp. 181–185. 1903. 25c.

——— Copper deposits in Georgia. In Bulletin No. 225, pp. 180–181. 1904. 35c.

——— The Griggstown, N. J., copper deposit. In Bulletin No. 225, pp. 187–189. 1904. 35c.

——— Notes on the copper mines of Vermont. In Bulletin No. 225, pp. 190–199. 1904. 35c.

——— The copper production of the United States. In Bulletin No. 260, pp. 211–216. 1905. 40c.

——— The copper deposits of eastern United States. In Bulletin No. 260, pp. 217–220. 1905. 40c.

——— The copper mines of the United States in 1905. In Bulletin No. 285, pp. 93–124. 1906.

WEED, W. H., and PIRSSON, L. V. Geology of the Castle Mountain mining district, Montana. Bulletin No. 139. 164 pp. 1896.

WEEKS, F. B., and HEIKES, V. C. Notes on the Fort Hall mining district, Idaho. In Bulletin No. 340, pp. 175–183. 1908.

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LEAD AND ZINC.

THE TRES HERMANAS MINING DISTRICT, NEW MEXICO.

By WALDEMAR LINDGREN.

GENERAL FEATURES AND GEOLOGY.

About 25 miles south of Deming, N. Mex., and 10 miles north of the Mexican boundary the small group of mountains known as Tres Hermanas rises from the general level of the high plateau. The lead and zinc mining district is in the northern part of the group, the three peaks of which are in plain view from Deming. The road from Deming is almost level and has an elevation of 4,300 to 4,000 feet; on the east the crags of the Florida Mountains form a picturesque background to the plain, which is dotted by luxuriantly growing yuccas. According to Wheeler the highest peak of the Tres Hermanas attains an elevation of 7,151 feet. The railroad from Deming to Hermanas station is at the nearest point 10 miles from the mines, which as yet are most easily accessible from Deming.

The mines have been known for many years and have yielded a moderate production, possibly $200,000, principally from the Cincinnati vein and from the lead deposits in limestone near the present zinc mines. In 1904 zinc ores were discovered in the district, and in 1905 shipments were made to smelters in the Mississippi Valley, but in 1906 and 1907 there was little activity.

The geologic examination on which this paper is based was confined to the northern end of the district. It appears, however, that the predominating rock in the mountain group is a granite porphyry, which forms the central peaks and is intruded in Carboniferous limestones, which occupy the foothills. Specimens collected near the zinc mines show a coarse light brownish-gray porphyry with phenocrysts of feldspar up to 15 millimeters in length, small foils of biotite, and small crystals of dark-green hornblende. The

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microscope shows that the phenocrysts consist of orthoclase with some oligoclase and that the crystals are embedded in a coarse micropegmatitic groundmass of quartz and orthoclase. Possibly the rock is more correctly to be classified as a quartz syenite porphyry.

The northern foothills at the zinc mines consist of bluish-gray fossiliferous limestones of lower Carboniferous age dipping northwest at low angles. At the junction with the granite porphyry strong contact metamorphism is noted.

MINERAL DEPOSITS.

The mineral deposits consist of normal fissure veins in granite porphyry and typical contact-metamorphic deposits of lead and zinc in limestone near the contact with porphyry. Little work has lately been done on the veins, which are situated about 1 mile south of the zinc mines, but some information in regard to them was obtained from reliable sources.

The Cincinnati vein, owned by the Golden Cross and Eagle Company, is the largest producer, and is said to have yielded $100,000. It is stated to be a narrow vein in porphyry, very rich in lead and gold. The ore was found within 100 feet from the surface. Some ore has also been shipped from the Yellow Jacket vein, which is reported to be an extension of the Cincinnati. The Hancock vein, owned by C. E. Burdick, of Deming, is also said to be a narrow vein in porphyry, up to 8 inches wide. The shaft on this vein is 400 feet deep and some work was in progress in 1905. About 1,000 tons of rich lead ore, with some gold, is said to have been shipped.

The zinc mines are situated at the northern base of the first porphyry hills. Old surface workings indicate the places where formerly galena ores were mined. Even now pieces containing this mineral are occasionally found. In 1904 attention was attracted to a heavy white massive or crystallized material occurring plentifully in the old workings and it was found to consist of carbonates and silicates of zinc. The property, which consists of five claims forming a compact group, was worked by Thurman & Lindauer, of Deming, in 1905, and a considerable number of carloads of ore were shipped to Mississippi Valley smelters. Some difficulty was experienced in obtaining ore of the requisite high percentage, and the systematic and careful development that the property seemed to deserve was not undertaken and it was practically idle in 1906 and 1907. Another group of claims adjoining the property on the northwest is owned by Doctor Swope and associates, of Deming, and some ore containing zinc and lead was shipped in 1906. The railroad freight from Deming to the smelters is $5 a ton, and the hauling to the station costs $2 a ton. Ore containing 29 per cent of zinc was paid for

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by the smelters at about $11 a ton, and 37 per cent ore yielded approximately $16.50; obviously the lower grade left but little profit. The developments are slight, consisting of a few shallow inclines and surface cuts.

The traveler approaching Tres Hermanas from the north first encounters a low, broad limestone ridge, separated from the higher and more abrupt hills of porphyry on the south by a low gap. The principal zinc mines lie on the west side of this gap; the road leading up to it follows a broad gully, at first with a southeasterly direction, which close to the mines changes to due east. From the gap the plains are in full view, east and west. The main contact between limestone and porphyry runs east and west about a quarter of a mile to the south of the gap. The office of the Thurman & Lindauer property is situated in the gulch just west of the gap. The summit of the flat-topped limestone hill about 1,000 feet north-northwest of the office shows a moderately thick bed of bluish-gray limestone of lower Carboniferous age, highly fossiliferous in places. The strike is N. 80° E., the dip about 10° N. This series of limestones continues north-northwestward to the edge of the plains. In the little escarpment toward the gap the thin bed of fossiliferous rock is underlain by 5 feet of quartzitic limestone and below this lies a coarsely crystalline limestone. The gap is occupied by a similar coarse crystalline limestone with various dips and strikes; in one place, at some zinc prospects, a strike of N. 70° W. and a dip of 30° NNE. were noted. Nearer the porphyry hill the dip increases to 60°. About 1,000 feet west-southwest of the office at the principal workings there is a small hill with limestone which lies flat on the top, but bends to dips of 20° on the north, west, and south. The actual contact with the porphyry south of the gap is not very well exposed, but near it the limestone contains several well-defined dikes, and in one place a projecting broad tongue of porphyry distinctly cuts across the strata.

Contact metamorphism is clearly manifest, the affected zone being in places over 1,000 feet wide. The principal complex of limestone northwest of the gap is, on the whole, not metamorphosed, but even here, more than half a mile north of the contact, a few thin beds of garnet rock and coarsely crystalline limestone are noted. In the little bluff facing southward from the highest point where the fossiliferous limestone outcrops the beds underneath this member are distinctly altered to calcareous hornfels and coarsely crystalline limestone. In the gap the crystalline limestone prevails, with intercalated beds of pure garnet rock and hornfels, the latter evidently representing a contact-metamorphosed lime shale. Some of the strata exposed here contain well-preserved specimens of *Spirifer* and

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Fenestella and look like limestone, but, in fact, the rock consists very largely of garnet. The principal zinc workings, about 2,000 feet west of the gap, are in limestone, in which the only sign of alteration consists of bunches of wollastonite.

The deposits contain oxidized zinc minerals and some galena; they lie in part parallel with the stratification, but in part they follow short and ill-defined nearly perpendicular fissures and veins cutting across the beds and varying in strike from northwest to southwest. The ores also in places form irregular bunches in the limestone. Several small deposits of the two latter classes are present on the main limestone hill, in many of the prospect holes sunk there, but have not yet been proved to be of value. A short distance north of the principal gap oxidized zinc ores occur in kidneys and bunches between beds of coarsely crystalline limestone and garnet rock. A veinlike deposit striking N. 60° E. and standing nearly vertical also contains zinc ores at this place. Many of the prospect holes in the area of most intense contact metamorphism in the gap or immediately east of it have also given assays high in zinc. The principal developments, about 2,000 feet west of the gap, consist of surface pits and small shafts with irregular workings. Here the oxidized zinc ores occur in the greatest abundance, in part parallel to the strata, in part along a vein with west-northwest strike. Little intelligent propecting had been undertaken in 1905, the deepest hole having attained only 35 feet from the surface. The ore grades into limestone, and great care must be exercised to avoid mixing with barren material.

About 1,000 feet north of this place, on the Contention claim, Doctor Swope and his associates sunk an incline 150 feet long following the dip of the strata, which here was 30°. Some lead and zinc ores were shipped from this claim in 1906.

Systematic prospecting with drills would be necessary to develop these deposits. The principal ore bodies will no doubt be found intercalated between the flat-dipping strata.

As noted above, the galena was discovered at an early date, but the zinc ores escaped detection until recently. A few green stains are the only indications of copper minerals found. Possibly exploration may develop more of this metal in beds at greater depth. The galena was seen at the principal workings accompanied by a little pyrite and intimately intergrown with wollastonite in a manner indicating simultaneous deposition. The zinc ores occur as dark-gray cellular masses and consist largely of the unusual mineral willemite, the pure anhydrous silicate of zinc. Smithsonite, the zinc carbonate, is also present in its usual mammillary form and light-gray or bluish color. Hydrozincite was shown to be present by Doctor Hillebrand as an earthy incrustation. Tabular crystals of calamine, the hydrous silicate of zinc, were noted in crevices of the ore. Willemite appears to

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make up the bulk of the specimens collected. It is accompanied by a little black pyrolusite, which gives a dark tinge to the ore, and it forms small radial aggregates of slender hexagonal prisms, terminated by flat rhombohedra. It also forms loose crystalline aggregates and crusts of needle-like crystals. This habit is unusual, the more common form being a short, stout, hexagonal prism. The occurrence at Tres Hermanas seems to be paralleled only by that at Moresnet, in Belgium, where the willemite is also accompanied by galena. The only other occurrences noted in this country are at Franklin Furnace, N. J., and as rareties at Clifton, Ariz.,[a] and at the Merritt mine, in Socorro County, N. Mex. The zinc minerals of Tres Hermanas are beyond doubt derived from zinc blende by oxidation.

The principal zinc minerals of Tres Hermanas and their tenor are as follows:

Willemite (Zn_2SiO_4), zinc silicate, 58.6 per cent zinc.
Calamine ($H_2Zn_2SiO_5$), hydrous zinc silicate, 54.7 per cent zinc.
Smithsonite ($ZnCO_3$), zinc carbonate, 52.1 per cent zinc.
Hydrozincite ($ZnCO_3.2Zn(OH)_2$), basic zinc carbonate, 59.9 per cent zinc.

The zinc ores shipped from Tres Hermanas probably contained about 30 per cent of zinc. The shipments of lead-zinc ores made by Doctor Swope are stated to have contained from 11 to 40 per cent of lead and 2 ounces of silver to the ton. They also contained up to 19 per cent of zinc, 4 per cent of lime, 4.2 per cent of iron, and 7.40 per cent of silica.

An analysis of picked material from a loose aggregate of yellowish-white minute crystals gave the result recorded in column 1 below. Under 2 is given an analysis of a specimen fairly illustrating the average ore, but probably of lower grade than the material shipped.

Analyses of zinc ores from Tres Hermanas.

[Analyst, George Steiger.]

	1.	2.
SiO_2	23.52	9.12
$(FeAl)_2O_3$	.26	.22
ZnO	65.18	24.00
CaO	5.78	37.44
CO_2	4.59	29.05
H_2O-	None.	None.
H_2O+	.57	.71
MnO	None.	None.
	99.90	100.54

The first analysis gives willemite (Zn_2SiO_4), 82.75 per cent; calamine ($H_2Zn_2SiO_5$), 6.93 per cent; calcite ($CaCO_3$), 10.32 per cent;

[a] Lindgren, Waldemar, The copper deposits of the Clifton-Morenci district, Arizona; Prof. Paper U. S. Geol. Survey No. 43, 1905, p. 111.

[b] Genth, F. A., Contributions to mineralogy; Proc. Am. Philos. Soc., vol. 24, p. 37.

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smithsonite ($ZnCO_3$), 0.14 per cent; limonite, 0.31 per cent. The second analysis, the water being disregarded, gives rather closely 66.05 per cent of calcite and 32.77 per cent of willemite. As in the first analysis, the water above 110° C. indicates the presence of a small percentage of calamine. However, as in that analysis, the calamine must be calculated from the small quantity of water contained, which makes the exact amount uncertain.

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SURVEY PUBLICATIONS ON LEAD AND ZINC.

The following list includes the more important publications on lead and zinc published by the United States Geological Survey. In addition to the publications cited below certain of the geologic folios, especially the Joplin district folio (No. 148), the Lancaster-Mineral Point folio (No. 145), and the Franklin Furnace folio (No. 161), contain discussions of the lead and zinc resources of the districts of which they treat.

These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

ADAMS, G. I. Zinc and lead deposits of northern Arkansas. In Bulletin No. 213, pp. 187–196. 1903. 25c.

——— (See also Bain, H. F., Van Hise, C. R., and Adams, G. I.)

ADAMS, G. I., and others. Zinc and lead deposits of northern Arkansas. Professional Paper No. 24. 118 pp. 1904.

BAIN, H. F. Lead and zinc deposits of Illinois. In Bulletin No. 225, pp. 202–207. 1904. 35c.

——— Lead and zinc resources of the United States. In Bulletin No. 260, pp. 251–273. 1905. 40c.

——— A Nevada zinc deposit. In Bulletin No. 285, pp. 166–169. 1906. 60c.

——— Zinc and lead deposits of the upper Mississippi Valley. Bulletin No. 294. 155 pp.

——— (See also Van Hise, C. R., and Bain, H. F.)

BAIN, H. F., VAN HISE, C. R., and ADAMS, G. I. Preliminary report on the lead and zinc deposits of the Ozark region [Mo.-Ark.] In Twenty-second Ann. Rept., pt. 2, pp. 23–228. 1902.

BOUTWELL, J. M. Lead. In Mineral Resources U. S. for 1906, pp. 439–457. 1907.[a] 50c.

——— Zinc. In Mineral Resources U. S. for 1906, pp. 459–489. 1907.[a] 50c.

CALKINS, F. C., and MACDONALD, D. F. A geologic reconnaissance in northern Idaho and northwestern Montana. (In preparation.)

CALKINS, F. C. (See Ransome, F. L., and Calkins, F. C.)

CLERC, F. L. The mining and metallurgy of lead and zinc in the United States. In Mineral Resources U. S. for 1882, pp. 358–386. 1883. 50c.

ELLIS, E. E. Zinc and lead mines near Dodgeville, Wis. In Bulletin No. 260, pp. 311–315. 1905. 40c.

[a] Earlier volumes of the Mineral Resources of the United States contain discussions relating to the lead and zinc industries of the United States.

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EMMONS, S. F. Geology and mining industry of Leadville, Colo., with atlas. Monograph XII. 870 pp. 1886. $8.40.

EMMONS, S. F., and IRVING, J. D. Downtown district of Leadville, Colo. Bulletin No. 320. 72 pp. 1907.

GARREY, G. H. (See Spurr, J. E., and Garrey, G. H.)

GORDON, C. H. Mining districts of south-central New Mexico. (In preparation.)

GRANT, U. S. Zinc and lead deposits of southwestern Wisconsin. In Bulletin No. 260, pp. 304–310. 1905. 40c.

GRATON, L. C., and SIEBENTHAL, C. E. Silver, copper, lead, and zinc in the Central States in 1907. In Mineral Resources 1907, pt. 1, pp. 483–549. 1908.

HOFFMAN, H. O. Recent improvements in desilverizing lead in the United States. In Mineral Resources U. S. for 1883–84, pp. 462–473. 1885. 60c.

ILES, M. W. Lead slags. In Mineral Resources U. S. for 1883–84, pp. 440–462. 1885. 60c.

IRVING, J. D. (See Emmons, S. F., and Irving, J. D.)

KEITH, A. Recent zinc mining in East Tennessee. In Bulletin No. 225, pp. 208–213. 1904. 35c.

MCCASKEY, H. D. Gold, silver, copper, lead, and zinc in the eastern States. In Mineral Resources 1907, pt. 1, pp. 551–570. 1908.

MACDONALD, D. F. (See Calkins, F. C., and MacDonald, D. F.)

RANSOME, F. L. Ore deposits of the Cœur d'Alene district, Idaho. In Bulletin No. 260, pp. 274–303. 1905. 40c.

——— Report on the economic geology of the Silverton quadrangle, Colorado. Bulletin No. 182. 265 pp. 1901. 50c.

——— The ore deposits of the Rico Mountains, Colorado. In Twenty-second Ann. Rept., pt. 2, pp. 229–398. 1902.

RANSOME, F. L., and CALKINS, F. C. Geology and ore desposits of the Cœur d'Alene district, Idaho. Professional Paper No. 62. 1908.

SIEBENTHAL, C. E. Mineral resources of northeastern Oklahoma. In Bulletin No. 340, pp. 187–228. 1908.

——— Lead. In Mineral Resources U. S. for 1907, pt. 1, pp. 645–676. 1908.

——— Zinc. In Mineral Resources U. S. for 1907, pt. 1, pp. 659–676. 1908.

——— (See Graton, L. C., and Siebenthal, C. E.)

SMITH, G. O. Note on a mineral prospect in Maine. In Bulletin No. 315, pp. 118–119. 1907.

SMITH, W. S. T. Lead and zinc deposits of the Joplin district, Missouri-Kansas. In Bulletin No. 213, pp. 197–204. 1903. 25c.

——— (See also Ulrich, E. O., and Smith, W. S. T.)

SPENCER, A. C. The zinc deposits of Sussex County, N. J. In Ann. Rep. Geol. Sur. New Jersey for 1908. In press.

SPURR, J. E., and GARREY, G. H. Economic geology of the Georgetown quadrangle, together with the Empire district, Colorado, with general geology by S. H. Ball. Professional Paper No. 63. 1908.

ULRICH, E. O., and SMITH, W. S. T. Lead, zinc, and fluorspar deposits of western Kentucky. (In Bulletin No. 213, pp. 205–213. 1903. 25c.) Professional Paper No. 36. 218 pp. 1905.

VAN HISE, C. R. (See Bain, H. F., Van Hise, C. R., and Adams, G. I.)

WINSLOW, A. The disseminated lead ores of southeastern Missouri. Bulletin No. 132. 31 pp. 1896. Exhausted.

WOLFF, J. E. Zinc and manganese deposits of Franklin Furnace, N. J. In Bulletin No. 213, pp. 214–217. 1903. 25c.

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RARE METALS.

TIN, TUNGSTEN, AND TANTALUM DEPOSITS OF SOUTH DAKOTA.

By FRANK L. HESS.

INTRODUCTION.

Many articles have been written on the tin deposits of the Black Hills, and an excellent paper by J. D. Irving[a] on the tungsten deposits at Lead was published in 1901. Nothing is known to have been published on the tungsten deposits of the southern Black Hills, but several articles have been written on the deposits of tantalum. Nearly all the papers on these different deposits, however, are a number of years old, and later developments have given several of the deposits an aspect somewhat different from their appearance at the time they were described. It therefore seems well to give a brief account of observations made by the writer during a short reconnaissance trip in September, 1908, together with such reviews of the history and the literature of the region as may seem advisable.

All the known deposits of tin, tungsten, and tantalum in South Dakota occur in the Black Hills, in Lawrence and Pennington counties, in the southwestern part of the State. Although designated as "hills," these elevations reach a height of 7,216 feet in Harney Peak, 500 feet above the highest of the Appalachians (Mount Mitchell, 6,711 feet) and almost a thousand feet above the highest of the White Mountains (Mount Washington, 6,279 feet). They are about 60 to 75 miles long by 50 miles wide, the longer axis lying nearly north and south.

There is a considerable diversity of topography in the different parts of the area to be considered. In the southern part, near Hill City and Keystone, the hills exhibit rounded contours with fairly well

[a] Some recently exploited deposits of wolframite in the Black Hills of South Dakota: Trans. Am. Inst. Min. Eng., vol. 31, 1901, pp. 683-691.

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graded valleys, the only jagged or precipitous features being where the harder dikes of pegmatite or coarse granite have resisted erosion, while the more easily weathered schists have worn away.

North of Hill City, in the vicinity of Lead, the hills are flat topped at many places and the valleys are steep sided (though not precipitous), narrow, and deep. The flat tops are given to the hills by approximately horizontal Cambrian sandy dolomites and conglomerates unconformably overlying Algonkian schists which are more easily eroded.

Farther north lies the Tinton area, which resembles much of the country between Hill City and Keystone, though with a somewhat more marked relief, and on the east it is adjoined by the great Spearfish Canyon, which, were it on a great trunk railroad, would be one of the well-known scenic features of the country. The hills are covered with a fair growth of pine except where it has been cut off or burned.

Geologically the Black Hills consist of a central mass of granitic and metamorphic rocks from which dip away on all sides the concentrically outcropping younger rocks of the plains. The granite is a coarse pre-Cambrian pegmatitic intrusive cutting Algonkian schists which are exposed from Tinton to the region south of Hill City. The schists are amphibolitic, staurolitic, andalusitic, and quartzitic, in places containing a great many small garnets. There are also interbedded quartzites. The schists generally stand at a high angle, and on their eroded edges rests a Cambrian conglomerate, though in places the conglomerate is lacking and an overlying quartzite 10 to 25 feet thick takes its place. Above the quartzite are dolomite and shales. These are members of a series of Cambrian rocks which have been eroded from a large part of the area.

The schists are cut by numerous dikes of many kinds of igneous rock. Of these dikes this paper is most concerned with the pegmatites, which are particularly numerous in the Hill City, Keystone, and Tinton areas. A series of quartz veins are closely related to the pegmatites in the Hill City-Keystone area. With these dikes and veins the tin and tantalum deposits are inseparably connected. Tungsten ores are closely associated with them, but at Lead are also found, apparently with other relations. From place to place there is considerable difference in both the physical structure and the mineralogical composition of the pegmatites, especially as concerns the accessory minerals. This is particularly true in the southern hills.

The deposits of tin, tungsten, and tantalum are closely connected, both geographically and genetically, and though workable deposits carrying more than one of these minerals have not yet been proved, this is not out of the range of possibility.

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Tin deposits occur in the northern Black Hills at Tinton, and in the southern Black Hills near Hill City, Keystone, Oreville, and Custer.

Tungsten, in the form of wolframite, has been found sparingly at Tinton; in greater quantity at Lead, in the central hills; and at many places near Hill City. Scheelite has been found only occasionally and in small quantity.

Tantalum, in tantalite and columbite, has been found to a very small extent near Tinton and in considerable quantity near Keystone, whence there has been some output.

Tin was first discovered in the Black Hills in 1876, when Richard Pierce, of Denver, recognized cassiterite in placer gold from the northern part of the hills, and in 1877 Fred J. Cross identified it in material from Elk Gulch in the southern hills. It was not discovered in place until in June, 1883, when Maj. A. J. Simmons, of Rapid, sent specimens from the Etta mine, 2 miles south of Keystone, to San Francisco for determination.[a] The Etta claim was at that time being prospected for mica. Shortly afterward tin was found in place at Nigger Hill, since called Tinton, but at that time well known for its rich gold placers, part of which had been discovered by colored men, whence the hill received its name.

Owing to the lack of commercially valuable tin deposits in this country, great interest was awakened among both commercial and scientific men by the discovery. The former soon began plans for the exploitation of the deposits, while the latter studied the minerals and other phenomena connected with the occurrences, and the presence of wolframite and tantalite was soon determined. Companies were formed, and for about ten years there was great activity, though little production of tin. Since 1894 there has been much less done, and only two companies are now engaged in an earnest effort to mine tin, one at Hill City and one at Tinton.

No wolframite is known to have been mined until a number of years after the discovery of tin, when it was found in greatly different association and of much dissimilar appearance at Lead.

The value of tantalum was unknown at that time. In fact, it had little or no value beyond furnishing specimens for collections and material for a small amount of experimental work, so that for a number of years nothing was done toward saving the material except as it occurred in large lumps. The invention of the tantalum lamp gave an impetus to the demand in 1904 and 1905, since which time the market has been light.

[a] O'Harra, C. C., Mineral wealth of the Black Hills: Bull. South Dakota Geol. Survey No. 3, 1902, pp. 62-63. Headden, W. P., Notes upon the history of the discovery and occurrence of tin ore in the Black Hills; Proc. Col. Sci. Soc., vol. 3, 1888-1890, p. 347.

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TIN.

GENERAL OUTLINE.

Soon after the discovery of tin at the Etta mine, in 1883, a number of companies were formed to mine the metal. These companies were finally consolidated into the Harney Peak Tin Mining, Milling and Manufacturing Company, with English and American capital. Three million dollars of English money is said to have been sunk in the enterprise, but the amount of American money is unknown.[a] Offices were established at Hill City, and a great number of claims, said to be about 1,100,[a] averaging 10 acres each, with a total area equal to 9 by 15 miles, were purchased over a length of 30 and a breadth of 10 or 11 miles. Apparently all operations and expenditures were on the same extravagant scale. Mills were put up about a mile east of Hill City and at the Etta mine, near Keystone, at a cost of many thousand dollars. The Etta mill alone is said to have cost $235,000.[a]

Shaft houses, boarding houses, or other buildings necessary for large operations were put up on the Etta, Matteen, Gertie, Cowboy, Addie, Mohawk, Coates, and other claims, work was undertaken on a considerable scale, and thousands of tons of pegmatite were broken down. This was easily done, as the pegmatite may be drilled and blasted without difficulty. Lying between the schist foliæ, it breaks with excellent, smooth walls, and the high dip of the dikes makes stoping easy.

Five thousand tons of ore which had been hauled from the various prospects was put through the mill in 1892 and yielded only one-fourth of 1 per cent of metallic tin.[b] This result was in great contrast with the estimates made by various men who had examined the properties, and was attributed to loss through unadjusted new machinery.

Estimates had been made by different examiners as follows:

Results of assays of Harney Peak tin ores.[c]

	Average number of pounds of black tin per long ton of rock.	Pounds of white metal yield per ton of 2,240 pounds.	Percentage of tin.
Prof. W. P. Blake	72.80	36.4	1.625
Prof. G. E. Bailey		134.4	6
E. N. Riotte	67.20		
Prof. H. O. Hoffman (reported test saved)	57.54	39.2	1.746
Estimates of Prof. C. M. Vincent	30	22.5	1
Professor Vincent's 69 samples (selected)		38.8	1.732
Estimates of Capt. Josiah Thomas	40	29.20	1.30

[a] Morse, A. J., The Harney Peak tin mines: Eng. and Min. Jour., vol. 58, 1894, p. 460.

[b] O'Harra, C. C., Mineral wealth of the Black Hills: Bull. South Dakota Geol. Survey No. 3, 1902, p. 67.

[c] Rolker, C. M., The production of tin in various parts of the world: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 533.

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The company went into the hands of a receiver in the summer of 1894. At the time the properties were visited (September, 1908) they were still under the control of the court. A large proportion of the claims were allowed to lapse, as they were not considered worth patenting.

During the entire operation of this company probably less than 5 tons of metallic tin was produced, far less than the weight of the gold coin put into the venture. Dr. A. R. Ledoux, the receiver, in a letter dated February 13, 1909, states that a settlement out of court has been effected and that a careful testing of the properties may be undertaken during 1909.

Since the collapse of the Harney Peak Tin Mining, Milling and Manufacturing Company a little tin has been taken out of the placers, both at Nigger Hill (Tinton) and in the southern field. One company—the Tinton Company—has endeavored to work the lode deposits at Tinton, and several companies have attempted to work the Gertie claim at Hill City. Litigation has made an already difficult situation worse, and little in the way of production has been accomplished at either place.

TIN DEPOSITS IN THE SOUTHERN BLACK HILLS.

GERTIE CLAIM.

The Gertie claim is located about half a mile south of Hill City, on the west side of Spring Creek, a short distance, possibly 100 feet, above the floor of the valley and a few hundred feet west of the Burlington Railroad and a public road. At the time visited (September, 1908) it was being operated by E. C. Johnson, who has been connected with the property for a number of years. The Gertie was formerly one of the claims of the Harney Peak Tin Mining, Milling and Manufacturing Company, but title was allowed to lapse and it was relocated by Mr. Johnson.

The basis of the location is in two nearly parallel pegmatite dikes. One of these, whose southeast end is close to the Gertie shaft and which is known as the "vertical" dike, is from a few inches to 4 or 5 feet wide and has a high and somewhat variable dip with a strike of N. 25° W. Although the strike of the dike is the same as that of the schist, it seems to have a steeper dip, so that it probably cuts the schist. Mr. Johnson states that the dike can be followed for three-quarters of a mile. Some prospecting has been done on the dike, and here and there crystals of cassiterite may be seen. In one prospect hole the dike is offset between 3 and 4 feet, almost horizontally, about 30 feet below the surface.

About 20 feet southwest of the southeast end of this dike is the other one, which on the surface reaches a maximum width of about

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3 feet. It may be followed readily for about 150 feet, and Mr. Johnson thinks he has found its continuation about a quarter of a mile to the southeast. The dike dips at an angle of 45° S. 78° W. and follows the schistosity.

The Harney Peak Tin Mining, Milling, and Manufacturing Company sunk an inclined shaft more than 400 feet along the dike, ran drifts each way, and stoped great quantities of pegmatite, most of which still lies in the stopes and is held from the levels by fast-decaying timbers. The Gertie Mining and Milling Company report having sunk the shaft to the 500-foot level (on the incline), where the dike was more than 8 feet thick. When visited, the mine was filled with water above the 400-foot level. It is probable that this dike is typical of most of the dikes of the region and that the phenomena which accompany it will be found to be more or less characteristic of others.

The dike was probably injected between the foliæ of the schists in a pasty condition, and the stresses developed through its being forced into place were not equal at all points, so that here and there the schists forming the sides of the dike were pressed almost together and in places met, squeezing out the pegmatite for some distance. This left the dike in irregular lens-shaped bodies. The different phases are excellently shown in the Gertie workings, and a good illustration of the phase in which the dike is wholly parted was printed in an article by Arthur J. Morse.[a] Precisely similar phases are shown diagrammatically in figure 8, drawn from a sketch of a quartz vein in the Forest City mine. That the squeezing took place before the crystallization and solidification of the dike was completed is shown by the fact that there is no noticeable distortion or crushing of the crystals.

The pegmatite, like all the pegmatites of the region, is light colored and fine grained through most of the dike. The quartz is glassy, partly colorless, and partly with a slight smoky tinge. The feldspar is probably albite in the main, though a thorough examination has not been made. The mica is muscovite and is peculiarly clear. In places the small books are almost as transparent as quartz, showing that there has been little or no bending or crushing of the rock since the crystallization of the minerals. Cassiterite and tourmaline occur in small amount as accessory minerals. No others are visible in the specimens collected, beyond a few small bright-green stains in the muscovite and a few rust stains. The dike is in places "frozen" to the walls and silicification extends into the schist an inch or more.

The cassiterite is dark brown in thin section, but appears to be black in the rock. The particles are of irregular shape, but tend to

[a] The Harney Peak tin mines: Eng. and Min Jour., vol. 58, 1894, p. 463.

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elongated tabular forms which vary in size with the texture of the pegmatite. In the fine-grained portions of the dike the cassiterite is in minute particles which may be barely visible. In the coarser portions of the dike the particles reach an inch in length, three-eighths of an inch in thickness, and two-thirds of an inch in width. So far as seen, the tourmaline also is black, and being in small particles it is with difficulty distinguished from cassiterite. It does not seem to accompany the cassiterite in the coarser parts of the dike, but occurs in the finer-grained parts, which makes distinguishment more difficult, particularly as the tourmaline crystals are short and those of cassiterite are elongated as compared with the usual habit of these minerals.

The cassiterite occurs in shoots which are apparently not very continuous in any direction, and no rules are known for their occurrence. In this dike, as in the other tin-bearing pegmatites of the region, many parts seem to be practically barren of tin.

The rock is easily crushed, and aside from the saving of slimed cassiterite probably the greatest difficulty in handling the ore arises from the large amount of mica it contains. A small mill and smelting plant, besides shaft houses, engines, pumps, and air compressor, have been erected.

BLUE BIRD CLAIM.

The Blue Bird claim is located on a short pegmatite dike 1½ miles south of Hill City on the north side of a small stream flowing into Spring Creek, which is nearly a mile to the east. The dike is 14 feet wide at the top and dips 65° E. Cassiterite is carried in veinlike portions of the dike, 1 inch to 2½ inches wide, composed of muscovite and quartz with little feldspar. The mica occurs in narrow aggregates up to one-half inch wide by 1½ to 1½ inches long, partly perpendicular to the indistinct walls of the veins.

The cassiterite in many places has a tabular form, but is largely anhedral,[a] having been crystallized contemporaneously with the other minerals, quartz, mica, and feldspar. Some particles, however, show their crystal form well, and these were probably the first to crystallize from the mass. Here and there crystals, which are probably twinned, are L-shaped. One specimen has legs that form a right angle and are five-sixteenths and one-half inch long by about one-eighth inch thick. The crystal is broken, so that its width is unknown.

At a depth of 40 feet the dike is crushed and pinches out through faulting, which has taken place since the solidification of the dike. A few feet of sinking and of drifting to the east have not shown the continuation of the dike.

[a] Anhedral—without crystal faces.

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OLYMPIA CLAIM.

The Olympia claim, owned by Henry Pettit, is on the south side of the rivulet near which the Blue Bird claim is situated, but a quarter of a mile nearer Spring Creek. The basis of the claim is a pegmatite dike 3 feet thick and several hundred feet long, with a dip of 45° to 55° N. 47° W. The dike is rather fine grained and at one place for a thickness of about 6 inches along the hanging wall contains considerable cassiterite. This portion of the dike is composed mostly of feathery mica and quartz. The mica is in plates an inch or more long by one-sixteenth to three-sixteenths inch wide in overlapping scales radiating in gently curved lines from an axis. The cassiterite is black, partly in tabular forms, reaching three-fourths of an inch in length by one-eighth inch in thickness and a little more in breadth. Most of it is in rather irregular flat grains following the lines of the mica.

The portion bearing cassiterite has been traced for 75 feet. A similar micaceous zone is seen along the foot wall in places, but carries less cassiterite. The middle part of the dike seems to contain little tin. No other accessory minerals were noticed.

TIN PLATE GROUP.

On the Tin Plate group of claims, held by James Angus and lying between the Olympia claim and Oreville (6 miles southwest of Hill City), several pegmatites were examined, of which some were similar in structure to the dike on the Olympia and others were coarser. Only a small amount of cassiterite was seen in any of the dikes. None of the pegmatite had been crushed and panned, however, and this treatment frequently will show cassiterite in some quantity where it is scarcely noticeable on the outside of the rock.

SALLIE CAVANAUGH CLAIM.

On the west side of the summit of a small hill west of Oreville, a collection of possibly a score of houses, Mrs. E. M. McDermott has a claim known as the Sallie Cavanaugh. It is on a coarse pegmatite dike reaching 25 feet in width by 500 feet in length and striking N. 10° E., with a nearly vertical westerly dip.

A rich bunch or short shoot of tin ore, which dips 20°–25° N., is exposed on this claim. The shoot is composed of coarse mica and quartz, with coarse cassiterite. Some of the mica plates are more than 2 inches across, and the cassiterite forms several veinlets one-half inch wide and a foot long. The shoot as exposed is about 2 feet wide and can be seen for only 6 or 7 feet. A few feet to the north

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another but less rich shoot was exposed. It was of somewhat greater width, but seemed to be nearly mined out. Almost no cassiterite can be found in other portions of the dike. The large, irregular pieces of cassiterite which occur in such coarse pegmatites are not composed of an aggregate of small crystal individuals which have grown together, as is the case with many large pieces from veins, but of masses which have segregated from the magmas in the same way as coarse quartz or mica, and have formed crystalline individuals either single or twinned.

The dike is somewhat irregular in thickness, and if shafts were sunk it would probably be found to pinch in places. The ore shoots as exposed, though rich, are not large, and their extent is uncertain.

On its lower side the dike rises 20 to 30 feet above the hill slope, and a considerable portion must have been eroded away. It seems probable, therefore, that in the stream bed not over 300 feet below there should be a placer which may be workable and should carry coarse cassiterite.

NAIAD QUEEN CLAIM.

The Naiad Queen claim, held by H. A. Albion, is situated on the north side of a valley one-eighth of a mile south of the Sallie Cavanaugh claim. The valley is possibly due to a fault. The claim is on a pegmatite dike 5 to 6 feet wide, dipping steeply N. 55° W. It has been followed for about 200 feet. A shallow shaft that has been sunk at one place is said to have contained some good ore, and smaller excavations have been made at several other points. The cassiterite is not so coarse or so conspicuous as on the Sallie Cavanaugh claim, and the rock would have to be tested to obtain any adequate idea of its richness.

TIN CITY CLAIM.

Frank Hebert holds the Tin City claim, adjoining the Naiad Queen on the northeast. It is located on what appears to be a lens of pegmatite about 8 feet thick, which shows in the side of a low hill and over which the schists have closed, as described in the notes on the Gertie mine. A short incline which ran into the dike was filled with water at the time visited (September 30, 1908), but good ore could be seen on one side.

LOUISE CLAIM.

The Louise claim, held by E. C. Hunt, is about a mile southwest of Oreville, on the west side of and several hundred feet above the Burlington Railroad and the wagon road which parallels it. Two pegmatite dikes outcrop on the steep hillside, whose general direction (N. 17° E.) they follow, with pinched places here and there, for more

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than half a mile toward Oreville. The dikes are about 75 feet apart at the point at which Mr. Hunt was prospecting. The lower dike is 3 to 4 feet thick, with a dip of 55° N. 73° W. Cassiterite is sprinkled through a shoot a foot thick in the middle of the dike. The length of the shoot along the dike was not clear, but could not have been many feet.

The upper dike is of coarser structure, is 5 to 6 feet thick, and shows but little cassiterite. It carries glassy, little-weathered spodumene, the largest crystals of which are from 3 to 8 inches thick by several feet long. The mineral includes some quartz and green tourmaline, and appears to be in two shoots a few feet wide. Apatite and lithiophilite, the latter coated with its decomposition product, purpurite, also occur in the dike.

At several places prospect holes and shallow shafts were dug by the Harney Peak Tin Mining, Milling and Manufacturing Company, or others, and some cassiterite may be seen in the dikes at these points.

FOREST CITY CLAIM.

The claim formerly known as the Clara Bell is now called the Forest City. It is (by road) about 6 miles south of Hill City and 1½ miles east of Oreville. The claim is being worked for gold, but at a depth of 250 feet and about 200 feet northeast of the shaft a tin-bearing pegmatite dike 3 feet 8 inches thick, of light color and fine grain, was cut. The cassiterite is in small pieces with black tourmaline particles of equal size, and is mostly in the outer 3 or 4 inches of the dike. The cassiterite is difficult to distinguish from the tourmaline, as both are black; the grains are small and of equal luster, and their occurrence together makes the dike appear much richer than it really is Feldspar is absent or in minute amount in this part of the dike; quartz occurs in granules, generally of small size, filling the spaces between the mica. The mica in the pegmatite is in narrow blades one-eighth to one-fourth inch across, the books of which are thinner than wide and stand at right angles to the wall.

Alfred Daney reported obtaining 1½ per cent of tin from samples taken across the dike. The dike is apparently not exposed at the surface, though other and larger pegmatite dikes are close at hand.

This dike is especially interesting from its close relationship to the gold-bearing quartz vein, which is probably 75 feet away. The vein is from 2 inches to 2 feet in thickness and in places is squeezed into lenticular masses like the pegmatite in the Gertie mine. (See fig. 8.) This squeezing suggests that the origin of the vein was similar to that of the pegmatite, and that it was not formed through gradual building up by percolating waters, but was squeezed through the rocks in

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a pasty mass. Relationship to the pegmatite is further suggested by the occurrence of black tourmaline in the vein. The tourmaline is in needles up to 2 inches long by one-sixteenth inch thick, confined to the outer 2 or 3 inches of the vein. Some muscovite occurs, but apparently only along the cracks in the quartz. Two granite dikes from 2 to 4 inches thick lie beneath and more or less parallel to the vein, but follow a zigzag course from nearly a contact to several feet away.

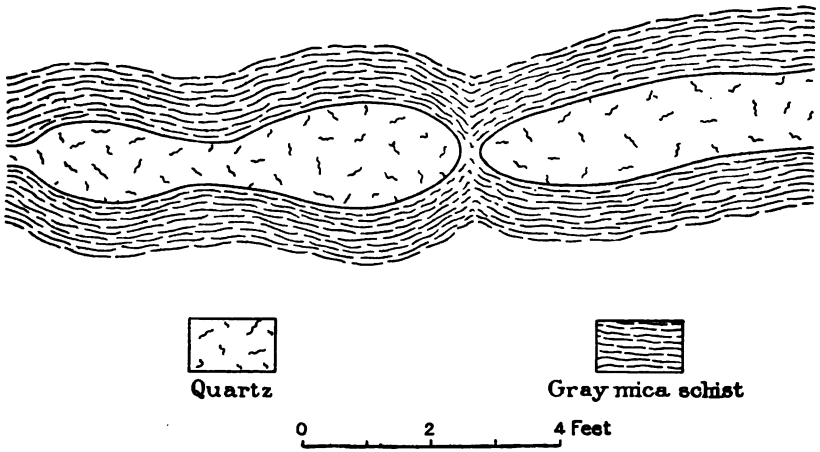

FIGURE 8.—Diagrammatic sketch of quartz vein in Forest City mine, 1¼ miles east of Oreville, S. Dak.

TIN QUEEN CLAIM.

On the Tin Queen claim, owned by Frank Hebert and lying east of the Forest City claim, are two large outcrops of pegmatite of rather coarse structure. The dikes appear to be lenses and to reach 50 feet in width. In the western dike is a shoot about 4 feet in diameter carrying a considerable sprinkling of cassiterite, ore which in quantity would undoubtedly be worth mining. The shoot contains a large amount of muscovite mica with quartz and very little or no feldspar; the parts of the dike carrying feldspar and less mica contain less tin. The cassiterite when crushed gives a purplish powder like some of the Carolina cassiterite and the mineral obtained at Tinton. Light-red garnets reach over an inch in diameter in the dike, but are crushed so that they can be extracted only in small fragments.

The other dike contains little visible cassiterite, but carries amblygonite in masses reaching several feet in diameter. Two carloads of amblygonite are said to have been shipped several years ago. The dike also carries lithiophilite, a blue-green apatite, vivianite, possibly another iron phosphate, dufrenite, and ilmenite.

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FIRST FIND CLAIM.

About 2 miles east of Oreville is the First Find claim, on which a pegmatite dike carrying cassiterite and columbite crops out boldly along the road, where it forms the southwest side of a small hill and is exposed for a width of 100 feet, though this is probably much more than the width of the dike, owing to the low dip. It is said that the dike can be followed for three-quarters of a mile to the northwest.

A small open cut has been made in the dike and some ore taken out. The cassiterite, so far as could be seen, is confined to a shoot a few feet wide and of uncertain extent and direction.

ANNIE NO. 1 CLAIM.

The Annie No. 1 claim, held by H. G., F. W., and William Mills, lies on the west side of Slaughterhouse Gulch near its junction with Allen Gulch, about half a mile west of the Hill City railroad station. In Slaughterhouse Gulch an open cut has been made which exposes a pegmatite dike carrying cassiterite and a quartz vein 4 to 6 feet wide carrying wolframite with some graphite on surfaces along which there has been movement. The pegmatite is somewhat wider than the quartz, and the latter is probably a segregation from the dike. The strike is N. 20° W., with a steep easterly dip.

In the pegmatite cassiterite occurs in irregular fragments and tabular aggregations, the latter reaching a breadth of several inches by one-eighth or one-quarter inch thick, and appearing to be thus flattened out as a result of crushing, as the cassiterite is greatly broken. Owing to their flattened condition the cassiterite masses resemble small veins. The portion of the dike in which the cassiterite occurs is almost wholly mica, most of the particles of which are oriented parallel to the flattening of the cassiterite. A little graphite occurs along slipping planes, and there is some black tourmaline. Besides quartz, feldspar, and muscovite, no other minerals were noted in the pegmatite proper.

In the quartz vein there is only a little cassiterite, but it carries some very black wolframite, though not, so far as exposed, in commercial quantity. Small particles of bismuth, in places altered to a carbonate, also occur through the quartz. There is here and there some muscovite. In places the foliæ of muscovite are coated brightly with graphite, so that when split apart they appear to be entirely composed of that substance, but rubbing uncovers the mica scales. Fifty feet east of this vein another quartz vein 8 to 10 feet wide has been exposed which runs N. 10° E. and dips 35° W. At the surface it shows many pittings partly filled with iron oxide, apparently indicating that the cavities were at one time filled with wolframite.

At the other end of the claim, about 1,000 feet N. 25° W., is a small exposure of greatly crushed, finely micaceous pegmatite, which shows

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cassiterite in thin seams similar to those at the south end. Near its center it holds a lenticular quartz mass about 1 foot wide by 2 feet long. The pegmatite is practically pinched off by faulting at the bottom of an 11-foot prospect hole.

No connection can be traced between the outcrops at the opposite ends of the claim, and they are probably disconnected lenticular masses.

TIN BOOM NO. 1 CLAIM.

The Tin Boom No. 1 claim, on the opposite side of Allen Gulch, is also held by the Messrs. Mills. It includes several dikes of cassiterite-bearing pegmatite.

Near the south end of the claim is a dike carrying glassy quartz in lenticular masses several inches thick, surrounded by fine-grained muscovite. The dike seems to be a transition stage between the pegmatite dikes and the quartz veins of the region and reaches a thickness of several feet. Cassiterite, in scattered particles and in veinlets similar to those on the Annie No. 1 claim, occurs in the mica, and the quartz contains pieces three-quarters of an inch or more thick and 3 inches wide by 10 inches long.

A second dike on the property, farther up Allen Gulch, has the normal structure of the pegmatite of the region; that is, it is a brittle mass of granular feldspar, muscovite, and quartz. It dips 63° N. 87° E., and a 35-foot shaft shows it to be 1 foot to 2 feet wide. At the shaft the dike carries cassiterite in irregular pieces reaching an inch in thickness.

A couple of hundred feet farther up the gulch what seems to be the same dike widens to 8 feet and shows a large percentage of white albite but very little cassiterite.

TIN BOOM NO. 2 CLAIM.

The Tin Boom No. 2 claim, also held by the Messrs. Mills, adjoins the Tin Boom No. 1 on the east. On the north end of the Tin Boom No. 2 is a 4-inch quartz vein, striking N. 10° W. and dipping steeply west, which carries some cassiterite in masses 2 or 3 inches broad by 1½ inches thick, generally accompanied by some muscovite. The cassiterite is lighter colored than that occurring in the pegmatite and is found along the vein for perhaps a hundred feet.

A short pegmatite dike a few inches wide crosses the vein at almost right angles and carries considerable cassiterite.

MOHAWK CLAIM.

The Mohawk claim, which still belongs to the Harney Peak Tin Mining, Milling and Manufacturing Company, adjoins the Tin Boom No. 2 and lies between it and Hill City. It has been considered one

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of the best claims belonging to the company, and considerable work was done on it, including a tunnel, now badly caved, and a shaft somewhat less than 100 feet deep.

The tin occurs in a shoot in a pegmatite, which has been somewhat squeezed, and the description of the cassiterite found on the Tin Boom No. 1 would apply here, but the prospects are better in the Mohawk.

OTHER CLAIMS.

Other claims in tne southern hills were visited, but showed either little tin or no features especially different from those of the deposits already described. Probably hundreds of dikes and veins carrying some tin were unvisited owing to lack of time. Among those seen which showed some special features, but are not described, were the Etta claim (which will be described under "Tantalum"), about 1½ miles by road south of Keystone; the Peerless claim, one-half mile nearer Keystone, where cassiterite is found in connection with amblygonite, lithiophilite, columbite, etc.; the Black Metal claims, described under "Tungsten," a mile north of Hill City; the Ottumwa claims, 4 miles east of Hill City, where cassiterite occurs in quartz veins with small amounts of wolframite, tourmaline, feldspar, and mica, and in a thin dike of quartzose pegmatite; and the Ingersoll claim, 8 miles east of Hill City, where a coarsely crystalline dike, 10 to 15 feet thick, carrying scattered fragments of cassiterite, is made up of albite, muscovite, and quartz, with pink, blue, green, and black tourmaline, lepidolite, lithiophilite, purpurite, and columbite.

TINTON AREA.

GENERAL OUTLINE.

The Tinton area is reached from the Spearfish branch of the Burlington Railroad at Iron Creek, whence a stage runs 8 miles west to Tinton, on Nigger Hill, close to the Wyoming line. Except for a mile at the beginning, the road is good for a mountainous country. Tinton, a collection of fourteen or fifteen houses, most of which belong to the Tinton Company, is situated on the flat top of Nigger Hill.

Spearfish Canyon, through which the railroad runs, is cut in Carboniferous (Pahasapa) limestone at the mouth of Iron Creek, up which the wagon road follows. In going from that point to Tinton the traveler crosses areas of Cambrian shales and sandstones and many dikes of various intrusives. Tinton is near the middle of an area of monzonite and syenite porphyries, which are considered by Darton and Smith [a] to be remnants of a laccolith. In this laccolith are areas

[a] Darton, N. H., and Smith, W. S. T., Sundance folio (No. 127), Geol. Atlas U. S., U. S. Geol. Survey, 1905, pp. 4, 8, 11, and 12.

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of schist, pegmatite dikes (Algonkian), and other intrusives much older than the laccolith, which is of Tertiary age. Darton and Smith conclude, therefore, that the pegmatites and other old rocks are floating in the porphyries and that ore deposits in the pegmatites can not be expected to last to great depth, owing to the fact that the dikes themselves are cut off at no great depth by the porphyries. To the present writer it seems an equally tenable hypothesis that the pegmatites, at least in those parts which are connected with considerable areas of schist, as at Tinton, may be masses that are now islands in the surrounding flood of porphyries and hold their original place with regard to the lower rocks.

Movement has broken the individual particles of the pegmatites all over the area. The cracks formed, which are generally minute, are filled with quartz or feldspar, with lesser amounts of mica. Like the other minerals, the cassiterite particles are seamed with quartz and feldspar. There appears to be more of a tendency for the cassiterite to take its crystal form in the Tinton region than in the localities observed in the southern hills, but good crystals can not be obtained on account of the crushing.

Some stream tin has been mined and shipped from Bear Gulch and other stream beds in the vicinity of Nigger Hill. Exploitation has been attempted for a number of years by the Tinton Company, and a mill has been erected about half a mile northwest of the workings, where a better supply of water is available. At the time visited (September, 1908) the mill was being overhauled and remodeled. A small amount of tin concentrates had been produced up to 1904, but none since then.

ROUGH AND READY CLAIM.

The principal claim of the Tinton Company is the Rough and Ready, located a few hundred feet southwest of the company's buildings, on a large pegmatite dike. The dimensions of the dike are uncertain, but it can be clearly followed from a point a short distance below the top of the hill on the west side for about 1,000 feet to the northeast, toward the company's buildings. The width of the dike can not be so easily told and probably varies considerably from point to point. At its widest it may be between 200 and 300 feet, with arms running north and south. The pegmatite is cut by many small dikes of hornblendic and diabasic rocks ranging from a few inches to several feet in thickness. Some of the hornblendic dikes are so crushed as to be schistose and seem from the greater crushing and alteration to be the older.

Two large open cuts have been made, one 100 by 200 feet and the other 50 by 100 feet. The former is probably 40 feet deep at most

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and the latter 30 feet. An adit, which has been run under the cuts, is 500 feet long and is in pegmatite all the way. It is said to have a depth of 85 feet at the end. The rock from the open cuts can be fed into the adit through chutes. Two drifts have been run. One, bearing nearly north, runs for 40 feet through gray mica schist, then strikes tin-bearing pegmatite, which it follows for 75 feet; a branch turning to the northeast runs for 100 feet through schist. The drift on the south runs through pegmatite for its whole length, probably 150 feet. The pegmatite is of the same general composition as the tin-bearing dikes of the southern Black Hills, but differs considerably in texture and composition from point to point. It shows in places a crushed phase in which grayish quartz occurs in plates as much as 4 inches long by three-eighths of an inch thick. At these places part of the feldspar is finely granular, but other portions are crystallized in individuals several inches thick. The cassiterite, although the individual particles are somewhat aligned with the quartz, was apparently crystallized after most of the crushing took place, as it shows less effect of the movements that fissured the other minerals. The appearance of the rock, owing to the different degree to which the various minerals are affected, suggests that the movement may have occurred when the crystallization of the mass was only partly complete.

In places there are bands or shoots of the pegmatite which are very micaceous, the individual plates or leaves of muscovite reaching a width of 2 inches. Slipping planes occur here and there and are coated with sericite, or in a few places with graphite and manganese oxide. The accessory minerals in the dike, besides cassiterite, are black tourmaline, pyrite, columbite, and, sparingly, a pretty blue-green mica in massive form.

The cassiterite occurs in shoots, the proportions of which are not easily ascertained, but which apparently have a flat lenticular or tabular form and are up to 5 or 6 feet thick, possibly more. Between these shoots the pegmatite undoubtedly carries some cassiterite, but probably in very small amount. Where the cassiterite occurs in the coarse mica shoots already mentioned it is in large pieces which reach 1 or 2 inches in longest dimension. In such shoots there is considerable quartz, but little feldspar. Cassiterite also occurs in shoots of feldspar with little quartz and mica, where it is generally in grains about the size of pop corn, or smaller. In fine mixtures of quartz, feldspar, and mica some of the cassiterite is in fine particles, aptly called "pepper tin." As in parts of the tin area of the Carolinas, the cassiterite on crushing gives a purplish powder and it is thus distinguished from tourmaline on this claim.

No original figures concerning the tin content of the rock can be given. Some parts are rich enough so that no doubt could be enter-

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tained as to the possibility of profitable exploitation, should these parts prove sufficiently large. Other parts are too lean to work, and the rock of this kind is probably in excess. Whether the mass as a whole can be worked at a profit, or whether the shoots alone can be worked, are problems which can be settled only by extensive sampling or a mill run. The company considers that they have been settled satisfactorily by its experiments and F. R. Carpenter,[a] after sampling the mine and rechecking his work, concludes that the pegmatite as a whole will run 0.75 per cent of metallic tin. He quotes Count de Rilly, Dunraven Young, and Doctor Carmichael as in practical agreement with him, the lowest estimate being 0.69 per cent.

OTHER CLAIMS.

Cassiterite is to be seen on many other claims in the vicinity, in every case in pegmatite dikes. None is known to have been found in any other rock, or in tin-bearing quartz veins similar to those near Hill City.

On the Tinton claim, about one-half mile northeast of the Rough and Ready claim, some rich ore is said to have been taken from a shallow incline. The cassiterite occurs with quartz, feldspar, and muscovite and has been in large crystals, but is now all more or less crushed. One remarkable lath-shaped crystal collected was 2⅝ inches long by three-sixteenths of an inch wide and one-sixteenth of an inch thick. About 1 inch of the crystal fell out in breaking away the specimen, but the impression is clear.

On the Iron claim there is some excellent tin ore in rather fine grained micaceous pegmatite, but its extent is unknown.

On a number of other claims in the vicinity tin ore was seen, but none were beyond the early prospecting stage.

SUMMARY, COMPARISONS, AND CONCLUSIONS.

The tin deposits of the Black Hills occur in pegmatites and in quartz. They are nowhere equally disseminated but occur in shoots.

The tin-bearing dikes, with a few notable exceptions, such as that on the Rough and Ready claim at Tinton and the Etta dike, are narrow, the widest other than these being about 25 feet in thickness, but most of them running from 1 to 7 or 8 feet. The quartz veins are ordinarily narrower than the dikes and probably represent the final segregation but one (the last being water) from granitic magmas.

The shoots of profitable tin-bearing rock are ordinarily of small cross section and of uncertain length (depth), and their occurrence in narrow dikes necessarily means that in general, except possibly at Tinton, they can be worked only on a small scale at each place

[a] Tin in the Black Hills, South Dakota: Min. World, vol. 25, 1906, pp. 600-601.

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and not, as is so often advertised, that "all that is needed to make them pay is to work them as low-grade propositions on a big scale." Possibly a solution of the problem of profitable exploitation would be the establishment of a central milling plant at Hill City which would take tin, tungsten, and, if the demand justified, tantalum ores, on a custom basis. This would give the men owning claims a chance to realize on the comparatively small amounts of good ore, running from 2 to 100 tons or more, which they would get out during a season, and the quantity of such ore that would thus be offered for sale would probably be sufficient to keep a 5 or 10 stamp mill busy, or a mill of other design of like capacity. An electromagnetic separating plant would be necessary to separate the tungsten and tantalum ores from the cassiterite. There is, of course, a possibility that much larger mines than are indicated here may be developed, but nothing was seen during this hasty reconnaissance to show such a likelihood, and local report did not refer to unseen properties as pointing to it.

The tin deposits of North and South Carolina, from which a small output has been made, are also in pegmatite dikes, and show a remarkable geologic similitude to the Black Hills occurrences, although they are not nearly so extensive. The age of the South Dakota dikes has been fixed by several investigators as pre-Cambrian; that of the dikes of the Carolinas as possibly late Paleozoic.[a] The pegmatite dikes of the two regions have been similarly forced into schists and have been given a lenticular form, and this form is exaggerated in the Carolinas. The appearance of many of the hand specimens from the two regions is similar, though, especially in the less stanniferous localities, there is in places extreme variation from the commoner types.

So far as known there is no place in the world which produces any considerable amount of tin ore directly from pegmatite dikes, though placers formed from them have been worked to a greater or less extent in France and South Africa. It is said that many of the veins from which the placer tin in the Malay Peninsula has been disintegrated are pegmatitic in character, but few or none of them are rich enough to pay for working.

Tin veins in granite, from which most of the world's lode tin is obtained, are, however, closely allied to pegmatites in that they have crystallized from emanations that were among the very last given off by granitic magmas. The likeness between the deposits of the two types is close, so that no reason is apparent why the deposits in pegmatites should not be as large and last as well as the better-known veins in granite.

[a] Keith, Arthur, personal communication.

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Tourmaline occurs in fair abundance in the dikes, reaching 1½ to 2 inches in diameter at Tinton. Columbite, tantalite, and wolframite are common accessories, though the last is known with the cassiterite of the region, except as a rarity, only in quartz veins. In those dikes which carry only a little cassiterite the list of accessory minerals is large. From the Etta mine the following minerals are enumerated by O'Harra:[a]

Minerals from Etta mine.

Albite.	Griphite.	Petalite.
Almandite.	Grossularite.	Quartz.
Andalusite.	Heterosite.	Rutile.
Apatite.	Ilmenite.	Scheelite.
Arsenopyrite.	Lepidolite.	Scorodite.
Autunite.	Leucopyrite.	Sphene.
Barite.	Liebnerite.	Spinel.
Beryl.	Löllingite.	Spodumene.
Biotite.	Melanite.	Stannite.
Bismuth.	Microcline.	Tantalite.
Columbite.	Molybdenite.	Tourmaline.
Corundum.	Monazite.	Triphyllite.
Cupro-cassiterite.	Muscovite.	Triplite.
Epidote.	Olivenite.	Wolframite.
Galena.[b]	Orthoclase.	Zircon.
Graphite.		

Chalcocite, apparently original, was collected by the writer from this dike in September, 1908.

The absence from these dikes of some minerals that generally accompany cassiterite is very noticeable. No topaz or axinite are known, and no fluorspar was seen by the writer. There is very little chalcopyrite or pyrite in the dikes.

TUNGSTEN.

GENERAL OUTLINE.

Tungsten ore is not known to have been produced commercially in the Black Hills except at Lead, though near Hill City a considerable number of tungsten-bearing veins and dikes have been discovered and a large amount of prospecting has been done. In this region wolframite is the tungsten ore of economic importance. Scheelite occurs sparingly, in some places as an original mineral and in others as an alteration product of wolframite. At Lead wolframite occurs in the form of impregnation deposits in a sandy dolomite. In the vicinity of Hill City the mineral is found in pegmatite dikes and in quartz veins which are probably a later product of the same igneous phenomena that caused the dikes. Wolframite is not known to be

[a] O'Harra, C. C., Mineral resources of South Dakota: Bull. South Dakota Geol. Survey No. 3, 1902, p. 64.

[b] It seems questionable whether galena, if found in the Etta dike, could have been an original mineral.—F. L. H.

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present in any considerable quantity in the pegmatites which carry cassiterite, and in fact it is known in only a couple of places in the dikes in quantity sufficiently large to encourage prospecting. In the quartz veins, however, wolframite and light-gray cassiterite are intimately associated.

DEPOSITS NEAR HILL CITY.

BLACK METAL CLAIMS.

On the Black Metal Mining Company's group of claims, a mile north of Hill City, there are a number of wolframite and cassiterite bearing quartz veins on which considerable development work has been done.

About 400 feet from the south end of the group, on the center line of Black Metal claim No. 3, which lies on the west side of China Gulch, is a quartz vein 6 to 8 inches wide striking N. 23° W., dipping steeply to the east, but almost vertical, and about 30 feet long. It cuts a gray fine-grained quartzose mica schist which strikes N. 75° W., with a dip of 35° N. 15° E. The walls are loose and show the effects of some slipping. The wolframite is of a bright, shining black color in irregular masses as much as an inch in thickness and several inches in length. So far as developed at the time, it was probably not rich enough to pay for mining. There is a small amount of muscovite mica, apparently following cracks in and thus later than the quartz. Thin seams of pyrites also follow cracks in the quartz. The wolframite decays, leaving in places a little scheelite, but generally only iron oxide. A similar vein, striking N. 88° W., with a steep dip to the north, though almost vertical, lies 42 feet farther south. This vein has been followed on the surface for 60 feet. It is faulted about 3 feet at the shaft. From the bottom of the shaft, which is 47 feet deep, the quartz showed pyrites along cracks and some that was possibly original.

Wolframite extends into the quartz from the sides of the vein in blades up to one-eighth of an inch thick and 2 inches long, which must have been formed either before or contemporaneously with the quartz. Like the other vein, this one is only a prospect, but it is one which encourages further work.

Farther north, on the west side of China Gulch, on Black Metal claim No. 5, is a quartz vein 9 to 12 inches thick, which is exposed in two prospect holes. The vein strikes N. 50°–55° E., dips 45° N. 35°–40° W., and has been followed for about 125 feet. It carries considerable black tourmaline in crystals an inch or more in length by one-sixteenth to one-eighth of an inch in thickness. Some wolframite is found mixed with light-colored cassiterite in masses up to 2 pounds in weight. The color of the cassiterite is in places hidden by stains of

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iron oxide. During the tin excitement this ground was held as a tin claim.

On Black Metal claim No. 6, near the north end of the group, is a quartz vein 6 to 8 inches thick, striking N. 5° W. and standing nearly vertical. A vertical shaft about 4 feet wide has been sunk, with the vein in the middle at the top. At a depth of 65 feet the vein is in the east wall of the shaft. The vein is generally free, but is in places "frozen" to the walls. The country rock, as in the other claims of the group, is quartzose mica schist, in places graphitic and here and there, near the vein, impregnated with small needles of black tourmaline.

The vein carries wolframite intimately intergrown with light-gray cassiterite, some of which is almost colorless. These minerals form tabular masses reaching 1½ inches in thickness and probably 8 to 10 inches in breadth. They occur near the middle of the vein, and C. G. Todd, in charge for the Black Metal Mining Company, stated that none had been seen on the sides of the vein. A granitic dike a few inches in width is said to lie along the vein in places, and at such points the vein is richest.

A small shaft house has been erected and drifts have been carried on the vein for about 30 feet each way at a depth of 65 feet. The vein is said to be widening a little toward the north. The shaft was full of water at the time of the writer's visit, so that it could not be descended. What seems to be the same vein is seen several hundred feet farther north, but it shows neither wolframite nor cassiterite at that point.

Southwest of this vein, on the same claim, is a quartz vein 4 to 8 inches thick, with a strike of N. 55° E. and a variable dip. It carries some wolframite, slender needles of black tourmaline, and some muscovite. In places thin branch veins enter the schist, which is here graphitic, and at some points bunches of wolframite occupy the whole width of the vein, so that the wolframite is said to be in the "slate," the name by which the schists are generally known in the locality. The vein is traced for only a short distance.

On Black Metal claim No. 7 a thin quartz vein carries wolframite, small pieces of green and white scheelite, brown cassiterite, pyrites, and a little mica. On Black Metal claim No. 8 is an irregular quartz vein that carries some wolframite and small particles of scheelite, original in the vein. Part of the scheelite is of a delicate green color. There is some cassiterite, which, where free from iron-oxide stains, is light gray in color, and some pyrites.

On Black Metal claim No. 1 a very small amount of brown cassiterite and green scheelite was found in dumps from prospect holes on quartz veins which carried albite, muscovite, and pyrite. On both claims 1 and 2 of this group are pegmatite dikes typical of the region,

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which carry a little blackish-brown cassiterite. In places quartz from all the dikes of the group shows white lines of minute air bubbles in a glassy groundmass, such as is common at many places in quartz connected with pegmatites.

GOOD LUCK CLAIM.

On the Good Luck claim of the American Tungsten Company, 3½ miles east of Hill City, a tungsten-bearing quartz vein 2 feet wide has been worked to some extent. The vein strikes N. 30° W. and dips southwest, underlying 15 feet in a depth of 40 feet. On the 40-foot level a drift follows the vein for 83 feet and reaches the surface on a hillside below the shaft house. The quartz shows white lines of minute cavities approximately parallel to the walls, and the wolframite occurs in roughly tabular aggregates that are also parallel to the walls. These aggregates reach a weight of probably 8 or 10 pounds. The wolframite is mostly brilliant black, but here and there a piece has the purplish rosiny appearance of hübnerite. Single cleavage blades reach perhaps 8 inches in length. The wolframite weathers into iron oxides, which fill some of the spaces left. In places the original structure of the wolframite may be seen in the iron-oxide skeleton loosely filling the cavity. A little scheelite appears to be formed by the alteration of the wolframite, but it may be original. A careful outlook was kept for tungstite formed by the breaking down of the wolframite, but none was found.

A very little scheelite, which is unquestionably original, of a light-green color, also occurs in the dike. Muscovite occurs along cracks in the quartz and in places penetrates the quartz to a depth of an inch, so that it was evidently a part of the dike, while the quartz was unsolidified and is an original mineral of the vein. The mica is in places mixed with graphite, probably collected from graphitic schists as the vein matter was forced through them. Graphite is not an uncommon mineral in the pegmatites of the Black Hills.

A shaft house, with hoist and engine, and a concentrating plant have been put up on the property. Other claims are held by the company, but were not visited owing to lack of time.

VIDA MAY CLAIM.

Four miles east of Hill City, and about a mile south of the Hill City and Keystone road, W. R. Pettit and John Nash have a claim known as the Vida May. The vein on which it is located is visible for less than 100 feet along the surface and is irregular in thickness, strike, and dip. The dip is 30° and more southward.

The dike occupies a fissure along an overthrust fault of unknown throw. At some points it reaches 10 inches in thickness and at

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others it pinches out. In the thicker part wolframite occurs in chunks, some of which are several inches thick. In places the dike pinches to half an inch and is almost wholly made up of wolframite. Some muscovite is present through the vein and shows a tendency to form in lines that give the vein a somewhat banded appearance.

One of the most remarkable features of the vein is a layer of impure graphite on each side from half an inch to 2½ inches thick. Muscovite occurs in this layer also and shows thin lines of minute flakes parallel to the vein. No structure of the graphite can be definitely made out. The graphite is undoubtedly segregated from the graphitic schists through the agency of the vein-forming materials. Smaller amounts of graphite have been noted at a number of places as included in the pegmatite dikes, but it seems significant that along quartz veins, the magmatic segregation which was probably most watery at the time of its intrusion, the most graphite should have been deposited. The same phenomenon was noted in Slaughterhouse Gulch. It is strongly suggested by these occurrences that the graphite is brought into solution by the hot waters accompanying the intrusion.

HENRY PETTIT AND OTHERS' CLAIM.

On the north side of Palmer Gulch, about 3½ miles southeast of Hill City, Henry Pettit and others have a claim located on a rather typical coarse pegmatite dike. The dike, which strikes N. 60° E. and dips northwest, occupies the brow of a hill. It is 30 feet or more thick at most, but thins toward the southwest and pinches out a few hundred feet from the middle of the claim. Three similar dikes lie within 300 feet down the hill to the southeast, and a fourth within 50 feet northwest of the southwest end of the dike. From the opposite side of the gulch the dikes look like stone walls, rising one above the other, holding up a terraced hillside.

In places the dike on which the claim is located is very coarse, and is cut transversely by smaller dikes as much as 2 feet in thickness. Some of the smaller dikes, 6 to 8 inches thick, carry wolframite in small amount, occupying cracks and crevices, and one dike contains a thin vein of solid wolframite one-eighth to one-fourth of an inch thick. In places this vein splits and each branch is as thick as the single vein. In one place a dike about 2 feet thick has decayed, leaving a trench several feet deep. Along the trench is a vein of iron oxides 2 to 3 inches thick, which probably is formed from the decomposition of either wolframite or pyrite. No tungsten can be detected in the oxides, but this seems to be the usual condition under such circumstances in this region. When wolframite decays the tungsten seems to be either left as scheelite or completely removed from the residual mass. Some pieces of the vein appear to bear a

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resemblance to crystallized wolframite, so that it seems quite possible that prospecting may show a vein of solid wolframite. The iron oxides carry some white chalcedony.

Quartz veins reaching 8 inches in thickness cut the dike and carry some wolframite.

WOLFRAM CLAIMS.

Three miles east of Oreville, on the west flank of Harney Peak, A. J. Reuchel, J. J. Sharp, and C. H. Cummings have four claims located on coarse pegmatitic dikes. At the upper end of the claims a dike in which wolframite has been found stands 30 to 40 feet above the surface, with a strike of N. 5° W. It is apparently vertical and 20 to 30 feet thick. On the south end of this prominent outcrop some wolframite occurs in irregular bunches an inch and more in thickness through a shoot not over 2 feet wide. At this place the pegmatite is composed of coarse feldspar and quartz with smaller bunches of muscovite. The claim which appeared to be the best of the four at the time visited is located below (northwest of) this place, at the junction of the dike just described with a second striking N. 40° W. At the junction the dikes are only a few feet wide, but they gradually widen as they separate and 100 feet away the second dike is as wide as the first.

The exposures were not good, but in the first dike a few feet from the junction wolframite occurred as thin plates, 1½ inches wide by one-sixteenth of an inch thick, interleaved with muscovite mica, and in coarser pieces in feldspar and in quartz, as well as in mixtures of the two. The crystallization is very imperfect and evidently was contemporaneous with the formation of the other minerals.

No tourmaline, cassiterite, lithia minerals, or other accessory minerals that are common to the dikes of the region were noticed in close connection with the wolframite, but a short distance away black tourmaline is found in the dikes.

PINE CREEK.

A specimen of wolframite given to the writer from the head of Pine Creek, 8 miles southeast of Hill City, weighs about a pound and shows rough crystal outlines. It contains a small amount of colorless scheelite and some biotite. This is the only biotite noted with any of the minerals treated in this paper.

DEPOSITS NEAR LEAD.

The deposits near Lead have been excellently described by J. D. Irving,[a] and beyond stating that so far the deposits have proved

[a] Some recently exploited deposits of wolframite in the Black Hills of South Dakota: Trans. Am. Inst. Min. Eng., vol. 31, 1901, pp. 683–695.

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small and that most of the ore in sight has been removed the present writer can add little to his description. The total amount of tungsten ore produced by the mines has been small, but may have reached 100 tons. Concerning the geology Irving states:[a]

"The metamorphic rocks of this area comprise a series of schists, phyllites, quartzites, amphibolites, and other varieties of crystalline rocks, everywhere tilted to a high angle, showing an advanced stage of metamorphism, and inclosing numerous intruded dikes of eruptive rock, chiefly rhyolite and phonolite. Unconformably upon the eroded surface of these upturned schists lie the nearly horizontal strata of the Cambrian, having at the base a conglomerate which varies from practically 0 to 22 feet in thickness, and above this (in certain portions of the Lead City area) layers of quartzite and loosely compacted sand. These beds are in some places highly auriferous. They constitute the so-called "fossil placers" so well described by Devereux,[b] and were in former years an important source of revenue in the hills. Indeed, at two of the mines mentioned in this paper, the Durango and the Harrison, wolframite has been extracted through the shafts and tunnels once used in exploiting these auriferous gravels. In the Yellow Creek area the basal conglomerate is thin and nonauriferous and passes by gradual transitions into a hard, dense quartzite, the two together constituting a bed which varies from 10 to 25 feet in thickness. Resting upon this quartzite (or, where that is poorly developed, directly upon the auriferous conglomerates) lie the ore-bearing beds, composed of a rather loose, shaly material, very heavily charged with iron oxides and the carbonates of lime and magnesia, and, in some places, so decomposed as to be a mere soft, earthy gouge, often stained with black oxide of manganese. If traced, however, to localities where decomposition is not so far advanced, it is found to be a dense, reddish-brown rock, showing many glistening facets of lime-magnesia carbonates, and sometimes exhibiting a well-marked stratified structure, due to the interposition of thin and often discontinuous layers of argillaceous shale. Microscopic and chemical examinations have shown this rock to be a crystalline dolomite. In other districts, where it is deeply buried and entirely unaltered, it is grayish blue and contains considerable glauconite. This ore-bearing rock is known among miners as "sand rock." The transition between it and the underlying quartzite is sometimes sharp; but in the two districts where the wolframite has been found it is gradual; the sand grains increasing in abundance as we go downward until the dolomite appears merely as a cement and finally disappears altogether. For this reason, and also because silicification has always occurred together with the deposition of the wolframite, the calcareous nature of the ore-bearing rocks has often been overlooked, and the deposits have been spoken of as "mineralized quartzite." This misconception should be avoided, because the process of mineralization has been one of replacement, and the original material replaced was in large part lime-magnesia carbonate, whether present as a cement or forming the body of the rock.

Above the dolomitic beds generally occur layers of shale, which become much more argillaceous and often contain considerable glauconite as one passes vertically upward. Above these shales, both in the vicinity of Lead City and Yellow Creek, are found remnants of a rhyolite sheet, showing in many cases a well-developed columnar structure.

Wolframite has been found at several points on the hills west of the Homestake mine at Lead, among them at the Hidden Fortune, the Harrison mine, and other properties, which are located on the ridge running northwestward and approximately in the same direc-

[a] Op. cit., pp. 686–687.

[b] The occurrence of gold in the Potsdam formation, Black Hills, Dakota: Trans., X, 465, et seq.

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tion as the strike of the schists and the open cuts of the Homestake mine. About 2½ miles S. 25° E., on a flat-topped hill west of Yellow Creek, gold-bearing wolframite deposits have been found in the Little Pittsburg, Wasp No. 2, and Two Strike mines. All these deposits occur in the flat-lying Cambrian rocks. None of the deposits could be studied in detail by the present writer owing to caving of the workings or other reasons. Irving's description of the occurrence is here quoted:[a]

The wolframite occurs in flat, horizontal but rather irregular masses, from nearly 0 to 2 feet thick. They frequently cover considerable areas, of which perhaps the largest so far discovered may be 20 to 30 square feet; but they are so extremely irregular that it is difficult to form an exact estimate of their lateral extent. These wolframite bodies are intimately associated with the flat masses or "shoots" of refractory siliceous ore, so extensively developed in the Black Hills of late years, which consist of an extremely hard, brittle rock, composed chiefly of secondary silica and carrying, when unoxidized, pyrite, fluorite, barite, and occasionally gypsum. Many cavities occur, lined with druses of minute quartz crystals, with clusters of purple or green fluorite or tabular crystals of barite. Oxidized portions are heavily stained with oxide of iron, and contain much infiltrated calcite, while the cavities often show drusy linings of jarosite. In the areas where the wolframite is found, the siliceous ore is always oxidized (no traces of original sulphides being discernible) and contains more barite than that from the other and more typical localities (the barite frequently forming as much as 50 per cent of the rock) and is usually of coarser texture. In form these bodies of siliceous ore are flat, channel-shaped masses, having in the districts under discussion a thickness of from 1 or 2 to 15 feet and ranging in length from 2 feet to as much (in rare instances) as 500 feet, while the width is from 5 or 6 to 50 feet or more.[b] The ore is usually banded, the banding being continuous with the bedding planes of the adjoining strata, and the shoots occur along lines of fracture termed "verticals," on either side of which the dolomite has been replaced from a fraction of an inch up to 12 feet in distance. Careful investigation of the ore bodies of this type shows that they are replacements of the dolomitic beds by silica, pyrite, and other accessory minerals. The mineralizing waters seem to have gained access to the soluble beds through the fractures and to have been confined to them by overlying impervious beds.

The ore is a mass of fine-grained wolframite in which the particles are in some specimens not over 0.01 inch across. In other specimens they are said to reach a width of one-fourth of an inch. Fresh pieces are bright black, showing the shining cleavage faces of the wolframite particles. When rubbed against other rocks the pieces have a dull brown and totally different appearance. Cavities are lined with minute crystals of wolframite. Some vugs also show white, yellow, or green scheelite. The latter two are noted by Irving,[c] but have not been seen by the present writer. Scheelite also occurs in small amount interstitially. Stibnite is stated by Irving to occur similarly.

[a] Op. cit., pp. 688–689.

[b] These dimensions refer only to the siliceous ore bodies found in the Lead City and Yellow Creek areas—the wolframite districts. The "shoots" in the Ruby Basin district are often of much greater size.

[c] Op. cit., p. 690.

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Irving concludes that the wolframite occupies its present position through metasomatic replacement of the limy and magnesian portions of the sandy dolomite—that is, as the lime and magnesia carbonates were dissolved wolframite was deposited in their place—that the same solutions that brought in the gold ores brought in the wolframite, and that the wolframite and gold belong to the same ore body.[a] This seems in accord with all the facts.

As to the origin of the ore, Irving believes that ascending solutions have dissolved the wolframite from older deposits below and transferred them to their present position. These older deposits he considers to be probably similar to those of the southern hills—that is, to be connected with pegmatitic or granitic rocks, or with quartz veins closely related to such rocks.[b]

To the present writer it seems more likely that the ores of the two areas are more closely related, genetically, than this hypothesis allows. It has been shown that in the southern hills wolframite occurs with ordinary pegmatites and with the later phases of such dikes that are seen in quartz veins. In the Lead region there are many rhyolite dikes, closely related in composition to the pegmatite dikes farther south. It is probable that either from them or from other intrusions closely related to a granitic magma watery portions separated, holding a more tenuous solution of quartz than that which made the quartz veins of the Hill City and Keystone region, so that veins were not formed, but instead the soluble carbonates were removed and replaced by the quartz, wolframite, scheelite, pyrite, gold, and other minerals held in solution. Irving predicted[c] that the deposits would probably not be of great commercial importance, and this prediction has proved true. The total output, though unknown, has not been large, but, as stated, possibly 100 tons. Little ore is left in sight, and there is no promise of production beyond small lots of a few tons now and then. Some ore is said to remain in the Hidden Treasure and Little Pittsburg claims.

TANTALUM.

GENERAL OUTLINE.

The mixture of tantalates and columbates ordinarily known as columbite when containing a preponderance of columbium or as tantalite when containing a larger percentage of tantalum has been found at a large number of places in the Black Hills and its distribution corresponds approximately with that of tin. Most of the minerals of this description found in South Dakota are properly classed as columbite, for most of them carry an excess of columbium. The occurrence of columbite in the Black Hills was first noted in print

[a] Op. cit., p. 694. [b] Op. cit., pp. 694–695. [c] Op. cit., p. 695.

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by W. P. Blake[a] in 1884, when he described a mass weighing a ton which he found on the Ingersoll claim.

As already stated, there was practically no demand for the material except for curiosities and mineral collections or experimental work, mostly chemical, until the invention and exploitation of the tantalum incandescent lamp in 1904. A temporary rise in price was caused by this demand, but it was supplied by a comparatively small output which came largely from Western Australia, where tantalum ores, especially manganotantalite, are found carrying 80 per cent or more of tantalum oxide (Ta_2O_5). The South Dakota minerals generally run much lower in tantalum oxide than the Western Australia ores, and naturally users prefer the richest ores to be obtained, other things being equal.

The analysis of columbite is very difficult, the separation of the tantalic and columbic compounds requiring discernment, skill, and patience beyond the ordinary, and when titanium is present it adds very largely to the difficulty. As such analyses are not often demanded of chemists, most of them have little practice in the separations, and it thus happens that there are not many who are capable of making satisfactory determinations. As ordinarily performed, the separation depends on the difference in solubility of the double fluorides of potassium and the metals, the tantalum salt crystallizing from the more dilute solution. An approximation of the amount of tantalum oxide present can sometimes be made by taking the specific gravity of the mineral, though specimens from different localities show considerable variation in this respect.

Like cassiterite, columbite (in which are included minerals containing much tantalum) is present in the pegmatite dikes of the Black Hills, and, so far as is known, only in them. This mineral was not seen in the quartz veins, which contain both cassiterite and wolframite. It is apparently a mineral that crystallizes before that stage of magmatic segregation in which the quartz veins originate is reached. The Western Australia columbium and tantalum minerals are also in pegmatite dikes or in placers derived from them.

Like cassiterite, columbite occurs in South Dakota in larger pieces in coarsely crystalline dikes than it does in dikes whose minerals are of small dimensions. In this region it forms, however, individual masses very much larger than those of cassiterite.

DETAILED DESCRIPTION OF DEPOSITS.

ETTA MINE.

The Etta mine, already referred to under "Tin," lies 1½ miles south of Keystone. A large mass, roughly circular in outline, of very coarse pegmatite is intruded into the schists and through its

[a] Am. Jour. Sci., 3d ser., vol. 41, 1884, pp. 340-341.

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resistance to erosion now forms the summit of a round hill about 300 feet above the valleys which lie on two sides of its base. The dike is about 150 by 200 feet in horizontal measurement. The minerals reach gigantic size, and the crystals of spodumene are probably unequaled by any other known occurrence, single crystals reaching 35 feet in length with a cross section of approximately 3 by 6 feet. No terminal planes were seen, but the prisms forming the body of the crystals are remarkably good. The spodumene is mined for the lithia contained in it. The material is considerably decomposed and resembles wood, so that the miners refer to the crystals as "logs." Some of the spodumene crystals form stars which radiate from masses 3 to 5 feet across, predominantly composed of honey-yellow muscovite and feldspar. In some places the feldspar is albite; in others microcline. The albite is in thin plates, and the microcline also shows partially crystal forms from one-half inch to several inches wide. The mica is in plates from one-eighth to three-fourths of an inch across. Through these masses are mixed other minerals in greater or less profusion—white beryl; small spodumene crystals; a dark metallic mineral in small crystals, the largest masses of which are little more than half an inch across; cassiterite, also in small particles; quartz; secondary opal; and probably other feldspars and other minerals. Similar masses occur in other portions of the dike, but the component minerals differ in proportional quantity from point to point.

Cassiterite is said to have been found in the dike in masses weighing a number of pounds each, and, on account of similarity in color, columbite has often been mistaken for it.

In parts of the dike feldspar occurs in larger masses than in the portions described, and here columbite occurs in larger crystals and masses. One mass is reported to have weighed 600 pounds. The crystals are embedded in the feldspar (mostly microcline where in large masses, with some albite), but the columbite is also associated with quartz, albite, muscovite, and beryl, in the last of which it may be wholly immersed.

All the crystals seen are tabular and run from a small fraction of an inch to several inches in width; they are somewhat longer than wide and comparatively thin. The proportions between the dimensions vary considerably. The crystals grow into one another and inclose other minerals. Internally many of the crystals show peculiar shining pencil-shaped surfaces, which may be due to this intergrowth.

A small amount of columbite has been mined in connection with spodumene mining and many hundred pounds of it has found its way into private and public collections of minerals, but the whole makes a comparatively small tonnage. The dike contains some ilmenite, leucopyrite (iron arsenide), and a few other heavy minerals

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which could not be separated mechanically from the columbite but might easily be parted electromagnetically.

W. P. Headden made a series of analyses of columbite specimens from the Etta mine, the results of which were published in 1891.[a] His determinations were made entirely on comparatively large crystals. The specific gravity and the columbium oxide and tantalum oxide content, as determined by Headden, are given below; his analyses also covered tin, iron, manganese, and calcium oxides, but do not mention titanium. Analyses by Headden of material from other portions of the Black Hills are also given in the original article.

Parts of analyses of columbites from the Etta mine.

	Specific gravity.	Cb_2O_5.	Ta_2O_5.		Specific gravity.	Cb_2O_5.	Ta_2O_5.
1	5.890	54.09	18.20	6a	6.612	35.11	47.11
2	6.181	47.05	34.04	6b		35.17	47.08
3	6.245	46.59	35.14	7a		31.80	52.14
4	6.376	40.37	41.14	7b	6.707	31.31	52.49
5	6.515	39.94	42.96	8	6.750	29.78	53.28

It will be noticed at once that there is a wide range in the tantalum content of columbite from the same dike, so that in the sale of columbite a great difference in the content of different lots might and probably would occur, and to obtain the average content of any lot would require the most careful sampling. No analysis of the fine-grained metallic mineral is known to have been published hitherto, and as it was supposed to be columbite in smaller crystals, in order to get some means of comparison with the larger crystals an analysis of material collected by the writer was undertaken by R. C. Wells, of the United States Geological Survey. The material was obtained by crushing parts of hand specimens collected near the center of the dike from the west side of the open cut made in mining for spodumene. In the specimens the largest mass of the mineral (an aggregate of small crystals) did not exceed one-half inch in diameter and most of the particles were less than one-eighth of an inch thick. Portions of two specimens, collected several feet apart, were crushed and panned down until apparently free from light-colored minerals. The specific gravity is 5.26.

Doctor Wells has found that the mineral contains a considerable amount of titanium, some iron, and probably both columbium and tantalum. The separation of these elements has proved so difficult that the analysis could not be completed in time for publication in this paper. The large amount of titanium suggested the possible presence of rutile, but a microscopic examination of the mineral failed to discover it.

[a] Headden, W. P., Columbite and tantalite from the Black Hills of South Dakota: Am. Jour. Sci., 3d ser., vol. 41, 1891, p. 95.

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Part of the material containing the mineral has been digested with hydrofluoric, sulphuric, and hydrochloric acids in an endeavor to discover crystal forms, but small movements in the dike have so shattered the mineral that no great success has yet been obtained.

OTHER OCCURRENCES.

As would be expected, tantalum minerals are found in the gravels of streams receiving the waste from dikes carrying such minerals. In Grizzly Bear Creek, flowing on the west side of the Etta pegmatite, between it and the Sarah claim, the mineral was found in working the gravels for gold and tin. In placer tin Headden found tantalite carrying a higher percentage of tantalum than any analyzed from the Etta mine.

Headden also mentions a mass of columbite exposed in the Sarah claim, one-quarter of a mile northwest of the Etta mine, which showed a section 8 by 14 inches. It was broken, and how much had been taken from it or how much was left could not be told. No other pieces were to be seen.

At the Peerless mine, one-half mile north of the Etta, large pieces of columbite are occasionally found. What is supposed to be the same mineral also occurs, in small particles not over one-sixteenth of an inch in diameter, distributed through a sugary yellow rock, made up almost wholly of muscovite mica and forming part of a large, coarsely crystallized pegmatite dike. The total amount of columbite in sight is not great. The dike is being mined for amblygonite, a mass of which 20 feet across has been exposed to a depth of 20 feet and for a length of 40 feet without reaching its limits. Several tons of lithiophilite have been collected in the course of mining and stacked up. On the west side of the dike there are poorly crystallized black tourmalines 2 to 3 inches in diameter. Muscovite occurs in plates several inches across, but they are feathery and worth little commercially. A little cassiterite is found in the dike.

The 2,000-pound mass of columbite found by W. P. Blake on the Ingersoll claim has been mentioned. Besides this, other large masses have been found. George Madill and his partner report having found a 500-pound mass in a claim being prospected for mica, on the south fork of Grizzly Bear Gulch, 2½ miles southwest of the Etta. A small specimen sent in shows the columbite in thin blades, with mica, feldspar, and quartz. Small amounts of columbite have been found in the stream gravels near Nigger Hill (Tinton) and a little is present in the dikes of the region.

Bock Brothers, of Hill City, have shipped some columbite mined near the head of Laughing Water Creek north of Custer, and small amounts of columbite have been reported from a number of claims in the vicinity.

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BIBLIOGRAPHY.

TIN.

BAILEY, GILBERT E., and RIOTTE, E. N. Harney Peak Tin Mining, Milling and Manufacturing Company. New York, 1886, p. 77.

Reports on the property of the company.

BENEDICT, WILLIAM DE L. Professor Vincent's estimate of possible profits of the Harney Peak tin mines (Dakota): Eng. and Min. Jour., vol. 48, 1889, pp. 358–359.

A brief review and criticism of Vincent's report on the mine.

BLAKE, W. P. The discovery of tin stone in the Black Hills of Dakota: Eng. and Min. Jour., vol. 36, 1883, pp. 145, 163, 164, 344; vol. 38, 1884, p. 69. Summary in Am. Jour. Sci., 3d ser., vol. 26, 1883, p. 235. Same material in Mineral Resources U. S. for 1883–84, U. S. Geol. Survey, 1885, pp. 592–640.

Reviews occurrence of tin in United States. Special description of Black Hills occurrence. Notes on foreign occurrences. A good paper.

CARPENTER, F. R. Tin in the Black Hills: Prel. Rept. Dakota School of Mines, 1888, pp. 133–166, 2 figs. Largely given in Ore deposits of the Black Hills of Dakota: Trans. Am. Inst. Min. Eng., vol. 17, pp. 588–598.

History of discovery; description of veins and inclosing rocks; accompanying minerals; analyses of cassiterite; estimates of richness of the ore, and treatment of the ore.

——— Tin in the Black Hills, South Dakota: Min. World, vol. 25, 1906, pp. 600–601. "Sketch showing formation of the Black Hills tin deposits."

Shows by quotations from various engineers, reports that tin exists in considerable quantities in the Black Hills. Believes that the Tinton district holds large possibilities for a great tin mine.

GARRISON, F. LYNWOOD. Tin in the Black Hills: Eng. and Min. Jour., vol. 78, 1904, p. 830.

Review of work done; geology of the district.

O'HARRA, CLEOPHAS C. The mineral wealth of the Black Hills: Bull. South Dakota Geol. Survey No. 3, 1902. Tin, pp. 62–67; tungsten, pp. 67–72.

General description of the tin deposits and a description of the tungsten deposits near Lead. The latter is largely taken from Irving's article.

ROLKER, CHARLES M. The production of tin in various parts of the world: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 530–535.

A general account of tin mining and prospects in South Dakota.

THOMAS, JOSIAH. Harney Peak tin mines: Eng. and Min. Jour., vol. 54, 1892, pp. 512–514, 536.

TANTALUM.

BLAKE, WILLIAM P. Columbite in the Black Hills of Dakota: Am. Jour. Sci., 3d ser., vol. 28, 1884, pp. 340–341.

Announces the discovery of a mass of columbite weighing 2,000 pounds on the Ingersoll claim.

HEADDEN, W. P. Columbite and tantalite from the Black Hills of South Dakota: Proc. Colorado Sci. Soc., vol. 3, 1888–1890, pp. 323–346. Also in Am. Jour. Sci., 3d ser., vol. 41, 1891, pp. 89–102.

Describes the occurrence of columbium and tantalum minerals in the Black Hills and gives analyses of columbite, tantalite, and manganese columbite. Analyses of tantalum-columbium minerals from other places are also given.

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SCHAEFFER, CHARLES A. Note on tantalite and other minerals accompanying the tin ore in the Black Hills: Trans. Am. Inst. Min. Eng., vol. 13, 1884–1885, pp. 231–233. Also Am. Jour. Sci., 3d ser., vol. 28, 1884, p. 430.

States that tantalite from the Etta mine examined by him contained no columbium.

TUNGSTEN.

IRVING, J. D. Some recently exploited deposits of wolframite in the Black Hills of South Dakota: Trans. Am. Inst. Min. Eng., vol. 31, 1901, pp. 683–695.

History of discovery, geology, and mineralogy of the wolframite deposits near Lead. Gives an analysis of the ore by W. F. Hillebrand.

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NOTE ON A WOLFRAMITE DEPOSIT IN THE WHETSTONE MOUNTAINS, ARIZONA.

By FRANK L. HESS.

About 12 miles south and a little east of Benson, Cochise County, Ariz., an attempt has been made to mine wolframite from deposits which are, so far as known to the writer, unlike anything heretofore described in the literature of ore deposits. Benson is at the west end of the El Paso and Southwestern System, on the main line of the Southern Pacific Railroad, and is the point from which the Southern Pacific's Sonora branch departs. The Whetstone Mountains, in which the deposits are situated, are one of the many short ranges of the region and lie directly south of the town.

The country has an elevation of 3,576 feet at Benson (Southern Pacific station). It is exceedingly dry and supports a poor growth of mesquite. The yucca gives a grateful touch of green to the landscape, and along the base of the mountains there are a few live oaks in the watercourses. The mountains are rugged and rocky. In the broad San Pedro Valley, with the Whetstone Mountains on the west and the Dragoon Mountains on the east, are irrigated patches of alfalfa, with tall bordering cottonwoods which are peculiarly beautiful in contrast with the bare surroundings. Part of the water for irrigation is obtained from small artesian wells said to be 300 to 400 feet deep.

The tungsten deposits lie on the eastern slope of the Whetstone Mountains between McGrew Spring and French Joe Canyon, half a mile from either place, at both of which water may be obtained. The locality is reached by a very fair road, and aneroid readings give it an elevation of 1,130 feet above Benson, or approximately 4,800 feet above sea level. The property was formerly worked by the Euclid Mining Company, but nothing has been done for a couple of years except to ship a few tons of ore (the entire output) which had been mined some time before.

The deposit is at the base of a steep rise, in granite which is intrusive in a series of metamorphic rocks, including siliceous mica schist and limestone. The wolframite occurs near the contact of the granite and schist and in a tongue of granite 60 or 70 feet long and perhaps half as wide which runs out into the schist. The granite is very light colored and, except in segregations to be described, contains no dark constituents.

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Half a dozen prospect holes, the deepest of which is down about 25 feet, have been sunk along a line running N. 55° E. (magnetic) within a distance of 200 yards. These holes either cut or are close to a white quartz vein which gradually dwindles at both ends, but in the middle attains a thickness of 2 feet. The vein has a steep dip to the northwest. At the time visited the holes all contained more or less water.

A little wolframite is found in the quartz vein accompanied by small amounts of mica, pyrite, bornite, and probably chalcopyrite. A more noteworthy quantity of wolframite occurs in segregations in the granite. The mineral is designated wolframite without a chemical analysis, as it is too black and opaque to be hübnerite, and fusion with soda gives the green color characteristic of manganese. Though this color is given by very small amounts of manganese, such as might be contained in ferberite (iron tungstate), the crystals are stumpy and the crystal terminations do not have the beautiful chisel shape of the ferberite of Boulder County. Some of the crystal faces are curved. Owing to their being wholly embedded in quartz, it has been impossible to make measurements of faces. The crystals are comparatively small and do not reach over one-half inch in length or three-sixteenths of an inch in thickness. The wolframite does not appear at many places in the vein. It occurs also in segregations in the granite similar to hornblendic and biotitic segregations in many other granites. The richer exposed deposits have been mined out, but there could not have been any very large ones, as the excavations are all small. The deposits still to be seen are lenticular in shape and are not over 2 feet long by a few inches broad. The breadth of the lenses could not be measured. In these segregations the wolframite varies considerably in the percentage it forms of the mass. In places there are small bunches of which much the larger part is wolframite, but it is said that as mined and hand picked the ore averaged 10 per cent WO_3.

The particles of wolframite in the granite are tabular and reach one-fourth inch in length. They are thin, the thickness probably averaging about one-sixth to one-fourth of the length and the breadth reaching two-thirds of the length. No parallel arrangement is noticeable. No scheelite is visible to the unaided eye, but in thin section the microscope shows a narrow band of a mineral which is probably scheelite bordering a portion of the wolframite. This band is so narrow that it is difficult to determine the matter decisively.

The segregations that have been worked have been close to the quartz vein mentioned, but there are other prospect holes 100 or more feet away, and one small lens of wolframite-bearing granite occurs 200 feet from the vein, up a small gulch. It is said that there is another occurrence on top of the hill above the workings, but the writer did not know of this until after his visit. Efforts were made for several years to work the deposits, and an air concentration plant was put up, but the quantity of ore did not prove to be large enough to pay for working.

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SURVEY PUBLICATIONS ON ANTIMONY, CHROMIUM, NICKEL, PLATINUM, QUICKSILVER, TIN, TUNGSTEN, URANIUM, VANADIUM, ETC.

The principal publications by the United States Geological Survey on the rarer metals are those named in the following list.

These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Publications marked "Exhausted" can not be procured from the Government.

BECKER, G. F. Geology of the quicksilver deposits of the Pacific slope, with atlas. Monograph XIII. 486 pp. 1888. $2.

——— Quicksilver ore deposits. In Mineral Resources U. S. for 1892, pp. 139–168. 1893. 50c.

BLAKE, W. P. Nickel; its ores, distribution, and metallurgy. In Mineral Resources U. S. for 1882, pp. 399–420. 1883. 50c.

——— Tin ores and deposits. In Mineral Resources U. S. for 1883–84, pp. 592–640. 1885. 60c.

BOUTWELL, J. M. Quicksilver. In Mineral Resources U. S. for 1906, pp. 491–499. 1907. Exhausted.

CHRISTY, S. B. Quicksilver reduction at New Almaden [Cal.]. In Mineral Resources U. S. for 1883–84, pp. 503–536. 1885. 60c.

COLLIER, A. J. Chromite or chromic iron ore. In Mineral Resources U. S. for 1906, pp. 541–542. 1907. Exhausted.

——— Tin ore at Spokane, Wash. In Bulletin No. 340, pp. 295–305. 1908.

DAY, D. T. Platinum. In Mineral Resources U. S. for 1906, pp. 551–562. 1907. Exhausted.

——— Platinum. In Mineral Resources U. S. for 1907, pt. 1, pp. 731–732. 1908. $1.

——— and RICHARDS, R. H. Investigations of black sands from placer mines. In Bulletin No. 285, pp. 150–164. 1906. 60c.

EMMONS, S. F. Platinum in copper ores in Wyoming. In Bulletin No. 213, pp. 94–97. 1903. 25c.

GALE, H. S. Carnotite in Rio Blanco County, Colorado. In Bulletin No. 315, pp. 110–117. 1907.

——— Carnotite and associated minerals in western Routt County, Colorado. In Bulletin No. 340, pp. 257–262.

GLENN, W. Chromic iron. In Seventeenth Ann. Rept., pt. 3, pp. 261–273. 1896.

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GRATON, L. C. The Carolina tin belt. In Bulletin No. 260, pp. 188–195. 1905. 40c.

——— Reconnaissance of some gold and tin deposits in the southern Appalachians. Bulletin No. 293. 134 pp. 1906.

——— (See also Hess, F. L., and Graton, L. C.)

HESS, F. L. Antimony. In Mineral Resources U. S. for 1906, pp. 511–516. 1907. Exhausted.

——— Bismuth. In Mineral Resources U. S. for 1906, p. 517. 1907. Exhausted.

——— Nickel, cobalt, tungsten, vanadium, molybdenum, titanium, uranium, and tantalum. In Mineral Resources U. S. for 1906, pp. 519–540. 1907. Exhausted.

——— Tin. In Mineral Resources U. S. for 1906, pp. 543–549. 1907. Exhausted.

——— Arsenic. In Mineral Resources U. S. for 1906, pp. 1055–1058. 1907. Exhausted.

——— Selenium. In Mineral Resources U. S. for 1906, p. 1271. 1907. Exhausted.

——— Some molybdenum deposits of Maine, Utah, and California. In Bulletin No. 340, pp. 231–240. 1908.

——— The Arkansas antimony deposits. In Bulletin No. 340, pp. 241–256. 1908.

——— Note on a tungsten-bearing vein near Raymond, California. In Bulletin No. 340, p. 271. 1908.

——— Minerals of the rare-earth metals at Baringer Hill, Llano County, Texas. In Bulletin No. 340, pp. 286–294. 1908.

——— Antimony. In Mineral Resources U. S. for 1907, pt. 1, pp. 707–710. 1908. $1.

——— Tungsten, nickel, cobalt, titanium, etc. In Mineral Resources U. S. for 1907, pt. 1, pp. 711–722. 1908. $1.

——— Tin. In Mineral Resources U. S. for 1907, pt. 1, pp. 725–729. 1908. $1.

——— and GRATON, L. C. The occurrence and distribution of tin. In Bulletin No. 260, pp. 161–187. 1905. 40c.

HILLEBRAND, W. F., and RANSOME, F. L. On carnotite and associated vanadiferous minerals in western Colorado. In Bulletin No. 262, pp. 9–31. 1905.

HOBBS, W. H. The old tungsten mine at Trumbull, Conn. In Twenty-second Ann. Rept., pt. 2, pp. 7–22. 1902.

——— Tungsten mining at Trumbull, Conn. In Bulletin No. 213, p. 98. 1903. 25c.

KAY, G. F. Nickel deposits of Nickel Mountain, Oregon. In Bulletin No. 315, pp. 120–127. 1907.

KEMP, J. F. Geological relations and distribution of platinum and associated metals. Bulletin No. 193. 95 pp. 1902. 30c.

MCCASKEY, H. D. Quicksilver. In Mineral Resources U. S. for 1907, pt. 1, pp. 677–692. 1908. $1.

PACKARD, R. L. Genesis of nickel ores. In Mineral Resources U. S. for 1892, pp. 170–177. 1893. 50c.

RANSOME, F. L. (See Hillebrand, W. F., and Ransome, F. L.)

RICHARDS, R. H. (See Day, D. T., and Richards, R. H.)

RICHARDSON, G. B. Tin in the Franklin Mountains, Texas. In Bulletin No. 285, pp. 146–149. 1906. 60c.

——— Antimony in southern Utah. In Bulletin No. 340, pp. 253–256. 1908.

ROLKER, C. M. The production of tin in various parts of the world. In Sixteenth Ann. Rept., pt. 3, pp. 458–538. 1895.

SCHALLER, W. T. (See Hillebrand, W. F., and Schaller, W. T.)

STERRETT, D. B. Monazite deposits of the Carolinas. In Bulletin No. 340, pp. 272–285. 1908.

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ULKE, T. Occurrence of tin ore in North Carolina and Virginia. In Mineral Resources U. S. for 1893, pp. 178–182. 1894. 50c.

WEED, W. H. The El Paso tin deposits [Texas]. Bulletin No. 178. 15 pp. 1901. 5c.

——— Tin deposits at El Paso, Tex. In Bulletin No. 213, pp. 99–102. 1903. 25c.

WEEKS, F. B. An occurrence of tungsten ore in eastern Nevada. In Twenty-first Ann. Rept., pt. 6, pp. 319–320. 1901.

——— Tungsten ore in eastern Nevada. In Bulletin No. 213, p. 103. 1903. 25c.

——— Tungsten deposits in the Snake Range, White Pine County, eastern Nevada. In Bulletin No. 340, pp. 263–270. 1908.

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IRON AND MANGANESE.

TONNAGE ESTIMATES OF CLINTON IRON ORE IN THE CHATTANOOGA REGION OF TENNESSEE, GEORGIA, AND ALABAMA.

By Ernest F. Burchard.

INTRODUCTION.

In the summer of 1906 and the autumn of 1908 the writer made a brief reconnaissance of the productive and possibly productive Clinton iron-ore fields within a radius of 80 miles of Chattanooga, Tenn. It is difficult to assign any definite limits to the Chattanooga region. In one sense it comprises the so-called Rockwood district and may be considered to extend as far southward as Gadsden and Attalla, Ala., and will be so considered here. The data gathered regarding the thickness, quality, and probable extent of the ore beds have been used in making preliminary estimates of tonnage of Clinton ore for the report of the Conservation Commission, which was submitted to the President in December, 1908.[a] In preparing these estimates the ore beds have, because of their broadly lenslike shape, been considered to be tabular bodies of varying thickness. In all estimates the average thickness used has been derived from as large a number of measurements as were available. The structure and attitude of the beds have been considered as determining their workability for given distances down the dip. A vertical depth of 1,000 feet below the level of the outcrop has been considered as the limit to which the ore might be regarded as workable under present conditions. Beds dipping uniformly at an angle of 25° would reach a depth of 1,000 feet at about 2,300 feet from the outcrop. With steeper dips, the distance would be much less; for instance, beds dipping at 50° would reach the 1,000-foot level at about 1,400 feet from the outcrop. For dips less than 25° the distances would be very much greater. The other factors that were considered besides the length, breadth, and average thickness of the

[a] The complete statistics of iron-ore reserves embodied in the conservation report are given in the paper by C. W. Hayes, reprinted in Bull. U. S. Geol. Survey No. 394, 1909.

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prisms of ore were the content of metallic iron and the percentage of probably recoverable ore. Some ore is invariably left for roofs or pillars in mining operations, and much is necessarily impossible of recovery on account of faults. About 80 to 90 per cent has been regarded as the recoverable proportion. The percentage of metallic iron controls not only the value of the ore, but also its specific gravity or number of cubic feet contained in a ton of ore. Ores are here considered as workable under present conditions that ten years ago were not mined owing to their low content of iron. With the exhaustion of the soft ores of the region, leaner and leaner hard ores have been utilized, owing to their high content of lime and low silica, which renders the material a suitable flux for brown ore or limonite. It is characteristic of the Clinton ores of this region that the hard ore is generally high in lime. Such ore, though originally low in iron, yields on weathering a soft ore rich in iron, and this accounts for the unusual richness of the soft ores that have been found in the region.

In the following pages is given an outline of the main facts on which are based the estimates of tonnage given on page 187. The figures given are, however, very much generalized and can not be regarded as at all close. Some of them may be too high, but it is believed that they are in the main conservative. They are the best that can be offered as a result of a very hasty and incomplete investigation, and it is hoped that what has been done may be only preliminary to a comprehensive study of the question of the origin and extent of the Clinton iron ores in the southern Appalachians.

ROCKWOOD DISTRICT.

LOCATION AND EXTENT.

The Rockwood district lies in the Tennessee River valley between Harriman and Dayton, Tenn., and extends eastward from the base of the Cumberland escarpment, or Walden Ridge, for about 10 miles. The area is principally in Roane County. Ore has been mined in many places along the west side of the valley between Spring City and Harriman, a distance of 25 miles. Adjacent to and underlying the river bed near the mouth of White Creek is a strip of Clinton (Rockwood) formation about 9 miles long. Ore has been mined at five or six places in this strip. The nearest post-office at present is Euchee. Six miles east of Euchee occurs another strip of Clinton (Rockwood) formation about 10 miles in length from northeast to southwest. Ore is mined at the upper end of this strip near Welker post-office.

Geologic maps of the district are contained in the Kingston folio (No. 4) of the Geologic Atlas of the United States.[a]

[a] The edition of this folio is exhausted, but the folio is on file in many public libraries, colleges, and engineering offices.

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The ore along Walden Ridge is within one-fourth to one-half mile of the Queen and Crescent and the Tennessee Central railroads. The ore at Euchee is carried by boat down Tennessee River to a point opposite Dayton, and the ore at Welker is also dependent on favorable conditions of the river for transportation from Seven Islands down to Caney Creek. Where the ore is carried partly by water private railways have been built to the river.

ROCKWOOD-CARDIFF AREA.

Along the southeast base of the Cumberland escarpment outcrop strips of the Clinton (Rockwood) formation, broken in places by faults which have interrupted the continuity of the formation and wedged in masses of Carboniferous rocks. The Clinton (Rockwood) formation is composed of shale, sandstone, and iron-ore beds. It forms generally a low ridge or line of foothills in front of the Cumberland escarpment. The beds dip to the northwest, passing below the Mississippian chert and limestone, which in turn are overlain in the Cumberland escarpment by masses of sandstone, shale, and beds of coal. Underlying the Clinton (Rockwood) formation to the southeast is the Chickamauga limestone, below which occurs the Knox dolomite, underlain by shale and sandstone of Cambrian age. The formation contains one bed of ore that is workable between Harriman and Rockwood, also at a few points south of Rockwood as far as Glen Alice. The normal thickness of the ore bed ranges from 2½ to 4 feet. The degree of dip of the Clinton (Rockwood) rocks and their inclosed ore beds varies greatly from place to place along the outcrop, and it is not at all uniform at right angles to the outcrop. In places the bed at the outcrop dips very steeply 75° to 80° NW. Where followed underground for distances of 20 to 100 feet along the dip, it may be found to be faulted and offset several feet. Commonly the broken edges of the bed are found to be shoved past each other so as to overlap, giving the impression that there are two beds of ore in the section. The dip of the ore beyond such a fault generally grows less until the bed is nearly flat, and in places the dip is reversed so that the bed rises to the northwest. Beyond such a rise, the bed is usually found to pitch down steeply or vertically for 40 to 60 feet and then to flatten again, and so on. A series of such folds has been encountered in the area between Rockwood and Cardiff, and some of them are overturned toward the southeast. From crest to crest the distances range between 40 to 100 feet, and in height the folds range from 15 to 60 feet. There is some variation in the strike of the beds, due to the fact that the axes of the folds are sinuous and, instead of lying flat, plunge at a low angle to the southwest. As a result of the plications in the strata, the ore bed has been squeezed

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in places to less than its normal thickness, and in others it is swelled to more than its normal thickness. The thickest portions occur generally along the axes of the troughs or at the tops of the arches. Where the bed is pinched down, it may be less than 18 inches in thickness; in the thickened places as much as 6.25 to 8 feet of ore has been observed. There are reasons for believing that this close folding took place below a great thickness of cover. The fact that movement has taken place between the particles of ore is plainly shown by the slickensided condition of ore fragments. The ore is also minutely jointed. Since the close folding took place the superincumbent beds have been largely removed by erosion and later adjustments of stresses have resulted in the faulting and overthrusting of beds near the surface.

Between Rockwood and Cardiff the normal thickness of the ore ranges from 2½ to 4 feet, including a few local shale partings or lenses one-half to 1 inch thick. The ore is fossiliferous red hematite. In places it is somewhat granular, resembling oolitic ore. On the outcrop the ore is "soft," the lime having been dissolved out; but below cover it is "hard" and contains lime. The soft ore has nearly all been mined from the outcrop by stripping and trenching and from shallow drifts. The hard ore now being mined carries 33 to 40 per cent of iron, 6 to 15 per cent of silica, 4 to 8 per cent of alumina, 10 to 17 per cent of lime, 2.5 to 3.5 per cent of magnesia, 0.15 to 0.3 per cent of manganese, 0.5 to 0.6 per cent of phosphorus, 0.015 to 0.2 per cent of sulphur, and 1.8 to 4 per cent of water. The specific gravity of the hard ore, as determined at the laboratories of the Roane Iron Company, ranges from 3.29 to 3.36, which corresponds to 10.9 and 10.68 cubic feet per ton of 2,240 pounds. South of Rockwood the ore becomes thinner, a bed 15 to 30 inches thick having been worked on the outcrop and from shallow drifts near Spring City and Glen Alice.

The principal mining development in this area is along a strip extending from Rockwood northeastward to Emory Gap, a distance of about 7½ miles. On this strip there were in October, 1908, eight slope mines in operation and eight slopes inactive. The slopes range in length from 150 to 1,000 feet. They are not driven so as to follow the ore, a course that would be physically impossible, owing to the folding of the beds. The slopes are consequently driven in rock below the ore at a pitch of 28° to 32° in a westerly direction, diagonal to the directions of both dip and strike of the ore bed. At intervals of 100 feet entries or "lifts" are turned off through the rock so as to intersect the ore from the foot-wall side. From each lift air ways or rooms are turned up to the lift above, a vertical distance of 30 feet, leaving a pillar of 20 feet between the rooms. Most of the ore is robbed from the pillars finally. The greatest

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distance from the outcrop in the direction of the dip that the ore has been opened is about 765 feet, but the actual number of feet of ore, measured on the ore bed, is much greater than this, owing to the folds. Mining under these conditions is difficult, but has been so well systematized here that very little ore is lost. The mines from Rockwood to Cardiff are operated by the Brown Mining Company, which supplies ore to the two furnaces of the Roane Iron Company, at Rockwood, the owner of the ore lands, besides selling some ore to the Citico Furnace at Chattanooga.

No prospect drilling has been done between the ends of the present slopes and the escarpment of Walden Ridge, so that the character of the ore beyond the present workings is unknown. Apparently there has been no diminution in the thickness of the beds at right angles to the outcrop so far as explored, and it is probable that the ore bed extends northwestward under the coal field to distances and depths too great for mining. It is understood that some of the present inactive slopes have been driven about to the limit of profitable mining under present conditions. To judge from the dip of the coal beds in the Cumberland Plateau, the ore should become less steep and less sharply folded where it passes beneath the coal measures, and therefore it is possible that conditions would be favorable for the extraction of some ore from the Cumberland area. As to the continuity of the ore for great distances below the coal measures, it may be stated that the Clinton (Rockwood) formation emerges in the anticlinal Sequatchie Valley, and that it does not carry workable ore in its north end opposite Spring. Conditions observed in many other Clinton areas indicate that the ore will deteriorate more abruptly in the direction of the dip than along the outcrop.

On the assumption that the ore which extends for 38,000 feet on the outcrop can be worked under present conditions for 2,000 feet from the outcrop, and under remote future conditions for 5,000 feet farther, there should be a supply of ore here approximating 15,000,000 long tons immediately available, and of 40,000,000 long tons in reserve. Considered in the same light, the thinner beds between Glen Alice and Rockwood possibly contain 2,500,000 long tons within the 1,000-foot limit and 7,500,000 long tons additional between the 1,000-foot limit and the 4,000-foot limit measured from the outcrop.

EUCHEE (CRESCENT).

The strip of Clinton (Rockwood) formation near Euchee extends along Tennessee River for about 9 miles, lying partly in Roane County and partly in Rhea County. Much of this strip is in the bottom land of Tennessee River and, as the river in its windings crosses the strip four times besides following the formation for some distance, much of the Clinton (Rockwood) area is below the river level. On the

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east side the Clinton (Rockwood) strip is bordered by a fault for about 5 miles. Near the county line on the outcrop the rocks dip 20° to 30° SE. The ore bed, as observed at the Crescent mine, is 5 to 6 feet thick. From 10 inches to 1 foot of lean ore at the top is left for a roof. The ore that is worked is seamed with shale and calcareous material so that the content of iron is rarely above 30 per cent in the hard ore and the lime content is greater than is necessary for blast-furnace practice. In the Crescent mine many small folds, diagonal to the strike of the beds, have been encountered. The faults are apparently all normal; that is, the rocks have slipped downward on the side toward which the fault plane inclines. The throw of the faults is very small, ranging from a few inches to about the thickness of the ore bed—5 or 6 feet. At right angles to the dip there are a few shallow rolls in which the ore becomes horizontal in places and rises slightly for a short distance toward the southeast. There are also a few strike faults within the mine, and one of these has been overthrust so that the ore bed is duplicated in the section at one point in the mine. Where the two portions of the ore bed that are overlapped are in contact the thickness of the minable ore is from 8 to 10 feet.

Soft ore has been mined in six or eight places along this strip on both sides of the river, and it is understood that nearly all the available soft ore has been obtained. The Crescent mine of the Dayton Coal and Iron Company was the only place visited in this area during the recent investigation. Hard ore is mined here from an underground slope about 600 feet long. The ore is shipped by boat down Tennessee River to a point opposite Dayton, and thence carried to the furnaces by railroad.

If this bed of ore averages 5 feet in thickness and extends for 16,000 feet on the outcrop and 1,000 feet on the dip, as the observed facts indicate, there should be approximately 3,500,000 long tons of hard ore available here.

WELKER.

Extending south-southwestward from Tennessee River, at a point about 3 miles above the mouth of Clinch River, is a prominent ridge, the crest of which is formed of sandstone of the Clinton (Rockwood) formation. About 4½ miles from the river the ridge is cut in two by a branch of Riley Creek which follows a low anticline whose axis is transverse to the major axis of folding. In the east slope of both parts of this ridge is a fairly thick bed of Clinton ore with a shale parting. The measures carrying the ore are folded into a syncline, having dips of 15° to 30° on the northwest limb and very steep to vertical dips on the southeast limb. The ore thus lies in two long, canoe-shaped synclinal basins, 4 to 4½ miles in length and about one-

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fourth to one-third mile wide. It outcrops on the limbs and at the ends of the synclines.

The ore in the northeast basin consists of two benches, the upper 5 feet thick, and the lower 2 feet thick, parted by 1 to 2 feet of shale. On the east limb of the syncline, where the beds are nearly vertical, the ore is soft to a depth of 150 feet in places. On the west limb the ore is soft on the outcrop for 300 to 400 feet where the cover is thin. The soft ore is very rich, carrying 45 to 50 per cent of iron. The hard ore is fossiliferous, high in lime, and lean in iron. The iron ranges from 25 to 36 per cent, the silica from 3.5 to 6 per cent, the alumina from 3 to 4 per cent, and the lime from 22 to 25 per cent.

In the southwest basin the ore lies in similar relations, having dips of 10° to 20° on the west limb and being vertical or overturned on the east limb. The ore occurs in two benches, the upper of which is 3 feet thick and the lower 2 feet thick. The shale parting is thicker here than in the area to the northeast, being about 6 feet thick. On the west limb the ore dips at nearly the same angle as the slope of the surface, so that it is under thin cover, and there is a large area underlain by soft ore that can be obtained by moderate stripping. The soft ore is of high grade, running in places above 55 per cent of iron. The ore in the lower bench is mostly hard and of lean to fair quality. Owing to its position, below 6 feet of shale, it can hardly be mined along with the upper bench, and probably would not be considered minable under present conditions.

Mining operations have been carried on only in the upper strip from a point near Tennessee River southwestward for about 3½ miles. A great deal of mining by stripping has been done here through a period of more than twenty years, and this form of mining is still in progress. Shale is being stripped to a maximum thickness of 30 feet near Hacklers Gap, although some of the ore thus uncovered is hard and rather lean. Ore is mined from the vertical or "upright" bed on the east limb of the syncline, adits being driven on the strike of the bed from both ends of a hill until they meet; then the ore is milled down through air ways into the adits. At the extreme north end of the basin, where the syncline "spoons" up to the surface near Tennessee River, the overlying shale has been removed from the ore beds. In October, 1908, the ore bed was still in place in the basin for 300 feet along the strike, showing most perfectly the nonsymmetrical synclinal structure that is characteristic of the whole deposit. The ore in this locality is owned and mined by the Roane Iron Company. The product is carried on the company's railroad from Welker to Tennessee River, where the cars of ore are transferred to a barge and towed by steamboat down the river to a point near the mouth of Caney Creek. Here they are picked up by a locomotive and hauled over a branch of the Cincinnati, New Orleans and Texas

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Pacific Railway as far as Cardiff. From this point the ore is carried over the main line of the same railway to the furnaces at Rockwood.

As the northeast basin contains an ore bed probably averaging 7 feet thick and extending 23,500 feet long on the strike and 1,650 feet at right angles to the strike, there should be 18,000,000 long tons of ore here available under present conditions. It is possible that in the middle of the basin the ore extends to a depth sufficient to increase the average distance on the total dip to more than 1,650 feet, and if so, the total tonnage will be increased proportionately. In the southwest basin, on the assumption that the upper bench averages 3 feet of ore for 20,000 feet on the strike and 1,700 feet on the dip, there should be 7,400,000 long tons available. Perhaps 1,000,000 tons, or possibly considerably more, of this total will be found to be soft ore. If the lower bench is found to average 2 feet of ore, it should contain about 4,775,000 long tons of ore in reserve. These estimates are all very rough and subject to revision.

CHATTANOOGA DISTRICT.

LOCATION AND EXTENT.

For the sake of convenience in subdividing the region, it will be here considered that the Chattanooga district comprises the ore-producing localities within the area limited by Sequatchie Valley on the west, Whiteoak Mountain on the east, Dayton, Tenn., on the north, and Rising Fawn, Ga., on the south.

The structure and distribution of the Clinton (Rockwood) formation and its ore-bearing areas in this district are shown on the economic geology maps of the Chattanooga (No. 6), Ringgold (No. 2), Rome (No. 78), Stevenson (No. 19), and Sewanee (No. 8) folios of the Geologic Atlas of the United States.

The areas containing workable ore are well supplied with railway facilities. The Southern Railway passes through the Ooltewah area; a branch of the Nashville, Chattanooga and St. Louis Railway extends up Sequatchie Valley; the Alabama Great Southern Railroad passes along the west border of the Lookout Mountain area; and the Chattanooga Southern and Central of Georgia railways are adjacent to the ore outcrops east of Lookout Mountain and Pigeon Mountain.

NORTH CHATTANOOGA.

At North Chattanooga, or Hill City, Clinton ore occurs in thin beds. The ore is inclosed in shale of the Clinton (Rockwood) formation, having very irregular structure. The beds are closely folded and considerably faulted, making deep or extensive mining practically impossible. One bed of ore, about 2.7 feet thick, has been mined to some extent on the outcrop and from shallow drifts. From a hasty

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inspection of this locality, it appears doubtful whether the ore can be considered available for more than 500 feet on the dip and for more than 1 mile on the outcrop, if all the available pieces of ore are placed end to end. This would provide 400,000 long tons of ore which would, for the most part, consist of soft or semihard material. The material can hardly be placed in the category of ore available under present conditions. Small quantities of ore have been obtained here in the past, and it is understood that mining is still in progress in a small way, the shipments being made by team to the furnace of the Citico Iron Company at Chattanooga.

INMAN.

On the east side of Sequatchie Valley, about 9 miles above the confluence of Sequatchie and Tennessee rivers, the outcrop of the Clinton (Rockwood) formation has been found to carry ore that is workable where soft. The beds dip at a low angle to the southeast below the Mississippian rocks that form the base of Walden Ridge. At this point mining operations were active for ten to fifteen years prior to 1903. At the time the old openings were visited in 1906 it was impossible to enter the mines for any great distance, owing to the badly caved-in condition of the workings. A limy ore bed, apparently about 4½ feet thick, but carrying only 2½ to 3 feet of good ore, has been worked here and more than 2,000,000 long tons of ore has been shipped, principally to the now abandoned blast furnaces of the Tennessee Coal, Iron and Railroad Company at South Pittsburg, Tenn. The surface workings extended for 2 miles along the outcrop and for more than 500 feet underground. Apparently little ore can be considered to be available under present conditions in this area. It is probable that with the future exhaustion of the supplies of higher-grade ore throughout the United States the hard ore in this locality will be considered of value at some time in the remote future, and on the strength of this probability a very general estimate has been made. The ore bed may be considered to average 2½ feet in thickness and to extend for 5,000 feet on the dip and for perhaps 15,000 feet on the outcrop, and these dimensions would indicate an ore reserve of 8,850,000 long tons. From such information as is available it seems probable that the hard ore will carry between 22 and 28 per cent, averaging about 24.5 per cent, of iron and an average of 30.7 per cent of lime.

OOLTEWAH.

About 2 miles east of Ooltewah, Tenn., ore-bearing strata of the Clinton (Rockwood) formation outcrop on both sides of a narrow syncline, the edges of which are exposed in Whiteoak Mountain and a smaller ridge lying about 2 miles east of it. The lower part of the

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formation here consists largely of hard brown sandstone, but the upper part contains more shale. Ore is present in the shale on the east slope of Whiteoak Mountain, the ore dipping 22° to 25° SE. There are, however, many minor crumplings in the strata that vary the dip considerably and make mining uncertain and difficult. The ore is very thin here, ranging from 14 to 18 inches in thickness, and in places having shale streaks included. Twenty years ago soft ore was obtained in large quantities from surface workings near the cuts of the Southern Railway through Julian Gap and McDaniel Gap and shipped to the furnaces at Chattanooga. At present, however, no ore for blast-furnace use is obtained here. Shallow surface workings are being operated by hand for the purpose of obtaining ore for the manufacture of metallic paint. In the ridge on the east limb of the Whiteoak Mountain syncline, north of Hinch's switch, red ore occurs apparently in two beds, but geologic examination has shown that a single bed of ore has been repeated by a close, overturned fold. Locally the same bed is displaced and repeated by an overthrust fault, and 1 mile south of Hinch's switch the entire Clinton (Rockwood) formation on the east limb of the syncline has been buried in a fault. The ore north of the railroad in this ridge averages about 12 inches in thickness, although in places it reaches 16 inches. Within the seam are a few partings of shale. From Hinch's switch northward for about 4 miles soft ore has been stripped for iron making in former years. At present the ore is mined by underground drifts and slopes at a point 1 mile north of the railroad. The product is shipped to the works of the Chattanooga Paint Company for use in the manufacture of metallic paint. If it is considered that the beds here have a total length of 35,000 feet on the outcrop, average 1¼ feet in thickness, and can be worked for 200 feet on the dip, there should be a reserve of 500,000 long tons of ore still in the ground. It should be noted, however, that this ore is not available for mining on a large scale under present conditions, and its principal value will probably remain, as at present, for its use as a paint material.

LOOKOUT CREEK.

Along the ridge lying just between Lookout Creek and the Alabama Great Southern Railroad, the Clinton (Rockwood) formation outcrops on what is structurally the west limb of the Lookout Mountain syncline. From Pudding Ridge northward through Trenton, New England, and Wildwood, Ga., to a point beyond the Tennessee-Georgia line the formation has been found to carry beds of iron ore that were workable on the outcrop. A bed of ore 2 to 2½ feet thick, dipping from 10° to 25° SE., has been mined on the outcrop near New England and at Wildwood. The ore obtainable by trenching

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or stripping is exhausted and mining activities are temporarily suspended. At Wildwood, however, where the soft ore has been found suitable for paint manufacture, there is still some ore available for that purpose. Geologic conditions indicate that there should still be a considerable reserve of hard ore in this locality, although there is practically no information at hand as to its quality. Persons familiar with the ore report that it carries only 22 to 30 per cent of iron. If the strips of ore between Wildwood and New England are considered as having a total length of 20,000 feet on the outcrop, as extending for 5,000 feet on the dip, and as averaging 2.37 feet thick, there should be an ore reserve here of approximately 12,650,000 long tons of ore; this is not available, however, under present conditions.

RISING FAWN.

In Johnson Crook, at the headwaters of Dry Creek, the Clinton (Rockwood) formation outcrops around the northeast end of a plunging anticline. The dips of the formation are to the north, northeast, and east into the synclinal Lookout Mountain area. Ore has been mined for many years in this vicinity to supply the blast furnace at Rising Fawn, Ga. Practically all of the soft ore has been exhausted from open-cut workings and the ore most recently mined (in 1906) was a rather lean, hard ore. The ore bed mined at that time averages about 4½ feet in thickness, and if it is considered to extend for 10,000 feet on the outcrop and 5,000 feet on the dip, there should be a reserve of about 12,500,000 long tons of ore at this place. The ore may in the near future possibly be worked to a depth of 1,000 feet by slope mining, and in this event 2,500,000 long tons of the amount just given should be available in the near future. West of Rising Fawn, at the Southwest end of Pudding Ridge, there is considerable low-grade hard ore present in the Clinton (Rockwood) formation. The ore has been prospected extensively, exposing a bed about 2½ feet thick that carries seams of shale and calcareous material. This bed can probably be worked in the remote future for 7,500 feet on the outcrop and 700 feet on the dip, and on this basis there should be a reserve of 850,000 long tons in the Pudding Ridge area west of Rising Fawn.

CHATTANOOGA CREEK.

On the east side of Lookout Mountain in Georgia, from Eagle Cliff southward for 10 miles, the Clinton (Rockwood) formation contains ore beds that have been worked at a few places for the soft ore that could be obtained on the outcrop. The formation dips at steep angles to the northwest or else stands vertical. At present no ore is being mined in this locality, but formerly some soft ore was obtained on the outcrop and from shallow slopes. Between Eagle

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Cliff and High Point the ore is about 2¼ feet thick and owing to its steep dip can not be mined to any great distance from the outcrop. On the assumption that there may be workable ore for 7,500 feet on the outcrop and extending to a depth of 1,200 feet, there should be an ore reserve here of 1,000,000 long tons, which can not be mined under present conditions.

About 2 miles east of Eagle Cliff a V-shaped area of the Clinton (Rockwood) formation is exposed by folding. Ore was being mined in this locality in 1906. There was still a little soft ore remaining which could be obtained by extending the stripping beyond the limit of former workings, and some hard ore was being taken from shallow slopes. This area can hardly be considered as containing any important amount of ore that is available under present conditions, but if the ore extends for 15,000 feet on the outcrop and 1,800 feet on the dip and maintains an average thickness of 2½ feet, there should be a reserve of 4,000,000 long tons of ore, not at present available. The iron content of the hard ore is understood to range between 22 and 23 per cent.

PIGEON MOUNTAIN.

Pigeon Mountain is a spur extending northeastward from Lookout Mountain in the southern part of Walker County, Ga. The rock structure in Pigeon Mountain is synclinal, the formations outcropping around the base of the mountain and dipping toward its axis. At Estelle the ore dips in general to the south and southeast. At the northeast end of the mountain, west of Copeland, the rock lies nearly flat, and where the formation swings around the southeast side of the ridge the dips are toward the northwest.

Near Estelle, for about 1 mile to the northeast and about 3 miles to the southwest of the Chattanooga Southern Railroad, the ore has been mined to a considerable extent on the outcrop and also from a number of drifts and tunnels. This area has been a large producer of soft ore in the past, most of it having been shipped to the furnace of the Southern Steel Company at Chattanooga. At present the mines are understood to be idle, owing to the suspension of operations by this company. Three beds of ore occur just below the middle of the Clinton (Rockwood) formation. They are about 25 feet apart, but only the lowest bed, which is 2½ feet thick, can be considered of much importance. The workable ore appears to extend at Estelle for at least 30,000 feet on the outcrop, and if it maintains an average thickness of 2½ feet for 2,500 feet on the dip, there should be about 13,000,000 long tons of ore available under present conditions. The geologic conditions indicate that this is a fairly safe estimate. If the ore should be exploited for 5,000 feet farther, there should be a

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tonnage of 25,000,000 long tons in reserve for remote future use. The hard ore here carries from 28 to 32 per cent of iron.

At the northeast end of the Pigeon Mountain syncline, about 2 miles west of Copeland Station on the Central of Georgia Railway, there is a large outcrop area of the Clinton (Rockwood) formation, which lies nearly flat around the end of the syncline. Several thin beds of shaly, limy, fossiliferous ore are present here. The thickest bed carries about 2.7 feet of ore parted by five or six seams of shale. The iron content ranges from 25 to 32 per cent. If this ore could be cleaned of its shale by means of picking or washing, the grade would be very materially improved. Although the beds lie flat and comparatively near the surface, there does not appear to be much soft ore in this locality. On the assumption that there is an outcrop at least 18,000 feet in length and that the ore could be mined for 2,500 feet on the dip, there should be a reserve of about 8,000,000 long tons available for future use.

On the southeast limb of the Pigeon Mountain syncline, in the vicinity of Bronco, the dip of the Clinton (Rockwood) rocks is rather steep toward the northwest and the outcrop is narrow. Soft ore has been mined along this outcrop from Sharpe to Chamberlain, a distance of more than 3 miles. At Bronco some underground work has been done and ore mined by means of shafts and slopes driven on the strike of the ore bed. The bed averages apparently about 2½ feet thick and if it maintains this thickness for 18,000 feet on the outcrop and 1,000 feet on the dip there should be a reserve of about 3,000,000 long tons in this locality available for future use.

TAYLOR RIDGE.

About 3½ miles southeast of Summerville, Ga., on the east slope of Taylor Ridge are beds of the ore-bearing Clinton (Rockwood) formation. These rocks dip about 24° SE. An ore bed about 18 inches thick occurs here, the soft ore of which has been mined by stripping. Some hard ore remains and can be obtained from drifts along the strike of the ore bed from its outcrop in ravines that cut the flank of the mountain. The geologic conditions indicate that the bed extends for 12,000 feet or more on the outcrop, and if it were possible to mine this bed for 1,500 feet on the dip there should be, approximately, about 1,800,000 long tons of ore here available for future mining.

DIRTSELLER MOUNTAIN.

At the north end of Dirtseller Mountain, 2 to 3 miles southwest of Lyerly, Ga., red ore has been obtained from surface workings for many years. The structure of the Dirtseller Mountain Clinton (Rockwood) area is synclinal, the ore dipping southeastward from

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the crest of the ridge toward Panther Creek and rising again to the southeast to form the crest of a lower ridge. The synclinal axis rises to the northeast so that the ore outcrops around the end of the syncline at a point about 2 miles west of Lyerly. The dip of the beds and the slope of Panther Creek are very nearly the same, and the ore bed is overlain, for the most part, by a comparatively thin cover, so that it has been possible to strip the ore for several miles along its outcrop and for several hundred feet on the dip. Mining is still in progress after this fashion, and a large tonnage of soft ore has been obtained here. The ore in reserve, however, is mainly lean, hard, fossil ore, carrying from 25 to 30 per cent of iron. The soft ore carries from 45 to 55 per cent of iron. It is probable that the whole tonnage of hard ore that remains may be mined under present conditions, providing the price of ore remains high enough to warrant the cost of mining. The ore bed as measured in about a dozen places averaged about 1½ feet thick. If it extends for 30,000 feet on the outcrop and to a distance of 1,000 feet on the dip, there should be about 3,000,000 tons of ore still available in this locality.

GADSDEN DISTRICT.

LOCATION AND EXTENT.

The area here included in the Gadsden district extends from Gadsden and Attalla, Ala., northeastward to the Alabama-Georgia line. On the northwest and southeast borders of the Lookout Mountain syncline, the Clinton (Rockwood) formation outcrops along Little Wills Valley and Wills Valley from Attalla to Battelle and in Shinbone Ridge from Gadsden northeastward, except where cut up by faults. Ore from mines in these strips of the formation is, for the most part, shipped to furnaces at Gadsden and Attalla, although some of it goes to furnaces at Chattanooga and Rome. The Alabama Great Southern Railroad passes along the west border of the Lookout Mountain area within about 1 mile of the outcrop of the ore, and on the east border the Chattanooga Southern Railroad lies even closer to the ore outcrop. Transportation facilities are entirely adequate to the development of the red-ore resources in this portion of the Clinton ore-bearing territory.

Maps of portions of the area are included in the Gadsden and Stevenson geologic folios (Nos. 35 and 19), and other portions are shown on the Fort Payne topographic map.

SHINBONE RIDGE.

From Gadsden northeastward the Clinton (Rockwood) formation in Shinbone Ridge carries ore, some of which is workable under pres-

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ent conditions and some of which can be considered workable only under remote future conditions. Near Gadsden the dips are steep—45° to 80° NW. Under a synclinal area, the opposite limb of which lies to the northeast of Attalla, the workable ore bed averages about 3.3 feet thick, and it has been mined by slopes which have been driven for 200 to 300 feet. The ore carries 30 to 40 per cent of iron, and if it extends for 6,000 feet on the outcrop and 2,000 feet on the dip, maintaining the same quality and thickness as is found in the mines, there should be approximately 2,900,000 long tons still available under present conditions.

If the various localities containing ore in the east border of the Lookout Mountain syncline or Shinbone Ridge, northeast of Gadsden, are considered, there is still a large tonnage of undeveloped ore that can be had for future use in this locality. The ore through much of the area carries 25 to 35 per cent of iron and will perhaps average 3 feet in thickness, but the structure is very irregular. Not only is the dip steep, but many faults occur which cut out the ore in places and will make mining difficult and expensive. If such strips of ore-bearing territory as are thought to be productive were placed end to end, there would be a linear extent of ore aggregating 10 miles on the outcrop, which can safely be considered to extend for 3,000 feet on the dip. The total ore contained in a mass of this extent would aggregate 31,821,000 long tons, but this amount must not be considered as available under present conditions.

WILLS VALLEY.

On the west border of the Lookout Mountain syncline from Rising Fawn, Ga., to Attalla, Ala., the Clinton (Rockwood) formation shows a narrow outcrop, with generally medium dips to the southeast. There are places, however, where the dip is 45° or greater. At Battelle, Ala., about 3½ miles from the Georgia state line, occurs a workable bed of ore 3.3 feet thick, dipping 23° to 45° SE. The soft ore has been stripped from the outcrop and the hard ore has been mined within the last four years on three slopes 200 to 300 feet long. It is not known definitely how far this ore may extend in workable thickness and character on the outcrop, but it is possible that 20,000 feet of ore may be considered as available. If it should continue for 2,000 feet on the dip with the thickness indicated above, there should be a reserve of 8,839,000 long tons available in the Battelle locality. It is understoood that the ore carries 24 to 32 per cent of metallic iron.

Near Portersville, Ala., ore of character similar to that at Battelle occurs in shale of the Clinton (Rockwood) formation, dipping about

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15° SE. Hard ore has been mined here from a slope that was about 400 feet long in 1905. The ore carries 25 to 38 per cent of metallic iron. The geologic conditions indicate that there should be at least 6,000 feet of ore on the outcrop averaging 3.3 feet in thickness and running 2,000 feet or more on the dip. This would give a reserve of 2,650,000 long tons of ore available under present conditions.

Near Crudup, Ala., about 7 miles northeast of Attalla, workable ore occurs in shale of the Clinton (Rockwood) formation, dipping about 26° SE. There are two beds of ore, the upper of which has been found to be workable. Soft ore has been mined on the outcrop and hard ore was mined in 1906 from two slopes about 1 mile apart. On the south slope the bed averages about 3¼ feet in thickness and on the north slope about 3¾ feet. The hard ore carries from 25 to 35 per cent of metallic iron. If it is considered that the ore at this locality extends for 7,500 feet on the outcrop and 1,500 feet on the dip and maintains an average thickness of 3¾ feet, there should be 2,280,000 long tons of ore here available under present conditions.

Near Attalla what is apparently the same bed of Clinton ore that occurs at Crudup has been mined for many years. All the soft ore has been mined from the outcrop and the hard ore is now obtained from two slopes about 2,000 feet apart that extended at the close of 1908 about 1,300 and 1,500 feet from the outcrop. The ore dips 30° to 35° SE., and ranges from 3 to 4 feet in thickness, averaging about 3½ feet. The geologic conditions indicate that the ore extends in workable condition for 7,500 feet or more on the outcrop, and 2,500 feet on the dip, which would give a tonnage of 5,000,000 long tons here available under present conditions.

As to the quantity of ore that may be obtained in the remote future from the west border of the Lookout Mountain syncline, there is room for great difference of opinion. Theoretically the ore should extend below the coal measures and emerge on the east side of the syncline and it undoubtedly does so, as is shown by the outcrops in Shinbone Ridge and Pigeon Mountain. The distance across the syncline is 10 miles or more in places, and it is likely that below the center of the syncline ore would lie comparatively flat and be freer of faults and other structural disturbances than along the outcrop. There are, however, probably changes in the character of the ore from the outcrop toward the center of the syncline. Beds which, on the outcrop, appear to thin out and change in quality may do likewise along the dip, and in the direction of the dip the change is probably more abrupt than it is along the outcrop. This statement is borne out by general observations of Clinton ore beds in various parts of the Appalachians. Strong evidence of the abrupt change of beds in the

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direction of the dip has been afforded by deep drill holes recently made in the Birmingham district. It is very evident that the beds on the east side of the Lookout Mountain syncline can not be correlated absolutely with those on the west side, and it is fair to presume that each bed thins out and gives place to succeeding beds of ore in the formation somewhere below the coal measures, so that the formation in reality contains several overlapping flattened lenses of red ore. The vertical depth at which the ore lies below the greater part of the Lookout Mountain syncline ranges between 1,300 and 3,500 feet. This fact of itself would preclude its consideration in this connection beyond the limits indicated above, and until mining conditions are such that ore can be mined at vertical depths exceeding 1,000 feet all the ore below that depth in the many synclines of the Appalachians in Tennesssee, Georgia, and Alabama must be regarded as completely beyond the present available limit. It is, however, fair to presume that there are at least 25 miles of outcrop of Clinton (Rockwood) formation that would carry a bed averaging 3 feet thick for 10,000 feet on the dip, without regard to the vertical depth that it would reach. A mass of ore having these dimensions, deducting 20 per cent for loss in mining, should carry 280,000,000 long tons. As the total outcrop of ore-bearing measures between Battelle and Attalla is more than 50 miles, and as 10,000 feet is but a fraction of the distance between the west border of the Lookout Mountain syncline and the east border, it is apparent that such an estimate as this can be considered conservative, especially with reference to ore beds that are not regarded as workable under present conditions.

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ANALYSES.

In the following table are given analyses of ore from nearly all the workings mentioned above.

Analyses of Clinton iron ores in the Chattanooga region.

Locality.	Authority.[a]	Fe.	SiO_2.	Al_2O_3.	CaO.	MgO.	Mn.	P.	S.	H_2O.
Rockwood-Cardiff:										
Hard ore—										
Wright slope	R.	35.10	8.08	5.27	14.00	2.59	0.15	0.60	0.84	.....
Patton slope	R.	40.55	7.88	6.03	9.90	3.49	.18	.59	.08	.....
Howard slope	R.	33.35	15.35	8.60	6.88	.....	.15	.60	.15	3.92
Warner slope	R.	38.00	4.61	5.85	10.85	4.23	.....	.....	.12	.....
Cardiff slope	R.	35.60	10.46	5.70	10.90	.....	.15	.59	.08	.....
Baker slope	R.	39.25	6.46	4.28	11.60	3.16	.....	.....	.08	.....
Suddath slope	R.	34.65	6.85	4.01	17.11	2.80	.36	.....	.07	.....
Glen Alice:										
Hard ore, Dyke slope	R.	38.08	10.60	.....	10.13	.....	.18	.56	.16	.....
Soft ore, surface	R.	50.19	12.58	9.82	1.15	.92	.....	.....	Trace.	.....
Euchee:										
Hard ore—										
Crescent slope	D.	26.50	9.10	6.28	22.25	1.43	.....	.416	.....	.....
Do	D.	29.80	5.42	5.06	21.78	1.60	.....	.....	.....	.....
Do	D.	32.00	7.69	5.58	18.45	1.48	.....	.416	.....	.....
Soft ore—										
River mines	D.	45.80	11.72	7.10	.....	.....	.....	.....	.....	.....
Do	D.	47.40	14.76	8.70	.....	.....	.....	.268	.....	.....
Welker:										
Hard ore	R.	25.20	3.48	3.25	25.15	1.84	.....	.....	.....	.....
Do	R.	36.90	6.10	3.01	14.10	1.83	.12	.38	.07	.....
Do	R.	29.06	7.00	3.79	22.97	1.20	.....	.....	.07	.....
Do	U. S.	36.30	7.92	3.07	13.77	1.71	.25	.57	.05	6.11
Do	U. S.	28.20	5.00	2.82	24.84	1.63	.23	.431	.05	5.61
Soft ore	R.	50.25	10.90	5.75	.....	.....	.....	.....	.....	.....
Do	U. S.	52.45	7.62	4.31	.40	.47	.23	.582	.02	10.01
Do	U. S.	49.76	7.63	3.64	1.68	.50	.44	.736	.07	8.99
North Chattanooga:										
Hard ore	R.	25.00	[b]11.+	.....	.....	.....	.....	.....	.....	.....
Soft ore	R.	45.+	[b]24.+	.....	.....	.....	.....	.....	.....	.....
Inman, hard ore	B.	27.93	7.07	.....	18.11	.....	.....	.282	.....	.....
Ooltewah:										
Soft ore	B.	56.00	16.45	.....	.....	.....	.....	.28	.10	.....
Do	B.	48.36	14.78	.....	.....	.....	.....	.63	.....	.....
Rising Fawn:										
Hard ore	O.	24.12	10.17	2.15	22.10	2.66	.21	.51	.005	.....
Do	O.	28.40	7.83	3.30	22.80	2.16	.40	.23	.....	.....
Pudding Ridge, hard ore	O.	33.25	5.50	.....	19.60	.....	.....	.....	.....	.....
Cenchatt, hard ore	O.	32.38	8.24	.....	21.52	.....	.....	.....	.....	.....
Eagle Cliff, semihard ore	D.	35.30	11.20	6.70	15.39	.....	1.60	.453	.....	.....
Estelle:										
Hard ore	R.	31.00	18.00	.....	.....	.....	.....	.....	.....	.....
Soft ore	R.	48.00	13.00	5.00	.....	.....	.....	.....	.....	.....
Dirtseller Mountain, soft ore	S.	49.55	15.87	5.87	2.61	.....	.....	.....	.....	.....
Battelle:										
Hard ore—										
Upper bed	L.	27.50	11.80		22.08	2.50	.....	.....	.....	.....
Do	L.	29.30	9.40		22.87	.....	.....	.....	.....	.....
Do	L.	31.18	7.20		22.54	.....	.....	.....	.....	.....
Do	L.	24.15	15.60		23.45	.....	.....	.....	.....	.....
Do	L.	23.25	12.90		26.05	.....	.....	.....	.....	.....
Bottom bed	L.	31.77	10.10		20.54	.....	.....	.....	.....	.....
Portersville:										
Hard ore	S.	25.52	5.60		30.82	.....	.....	.....	.....	.....
Do	S.	30.35	6.42		25.88	.....	.....	.....	.....	.....
Do	S.	33.72	4.94		22.90	.....	.....	.....	.....	.....
Do	S.	38.00	9.18		19.04	.....	.....	.....	.....	.....
Crudup: Hard ore	C.	39.07	10.58	3.30	14.13	.....	.13	.42	.....	.....
Attalla: Hard ore	W.	38.05	8.40	.....	27.00	.....	.....	.....	.....	.....

[a] Authorities: B, W. M. Bowron, Chattanooga, Tenn.; C, Central Coal and Iron Co., Holt, Ala.; D, Dayton Coal and Iron Co.; L, Lookout Mountain Iron Co.; O, owners of property; R, Roane Iron Co.; S, Southern Steel Co.; U. S., United States Geological Survey.

[b] Insoluble.

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SUMMARY OF TONNAGE ESTIMATES.

The following table gives a summary of the estimates of tonnage of ore in this region and of the data on which these estimates are based:

Extent, thickness, and estimated tonnage of Clinton ore beds in Chattanooga region.

Subdivision.	Length (feet).[a]	Width (feet).[b]	Thickness (feet).[c]	Iron (per cent).[d]	Ore (long tons).	
					Available.	Not at present available.
Rockwood-Cardiff	38,000	2,000 5,000	3.5 3.0	33-40	15,000,000	40,000,000
Glen Alice	15,000	1,000 3,000	..... 2.5	h. 30-38 s. 40-50	2,500,000	7,500,000
Euchee	16,000	1,000	5.0	h. 26-32 s. 45-50	3,500,000	.....
Welker (northeast basin)	23,500	1,650	7.0	h. 25-36 s. 40-50	18,000,000	.....
Welker (southwest basin)	20,000	1,700	3.0 2.0	s. 40-55 h. 25-30	7,400,000	4,775,000
North Chattanooga	5,000	500	2.7	h. 25-30 s. 38-45	.....	400,000
Inman	15,000	5,000	2.5	22-30	.....	8,850,000
Ooltewah	35,000	200	1.25	h. 30-35 s. 50-58	.....	500,000
New England-Wildwood	20,000	5,000	2.37	22-30	.....	12,650,000
Rising Fawn	10,000	1,000 4,000	4.5	20-30	2,500,000	 10,000,000
Pudding Ridge	7,500	700	2.5	20-33	.....	850,000
Cenchatt	7,500	1,200	2.25	25-32	.....	1,000,000
Eagle Cliff	15,000	1,800	2.5	25-33	.....	4,000,000
Estelle	30,000	2,500 5,000	2.5	28-35	13,000,000	25,000,000
Copeland	18,000	2,500	2.7	20-32	.....	8,000,000
Broncho	18,000	1,000	2.5	25-30	.....	3,000,000
Taylor Ridge	12,000	1,500	1.5	20-30	.....	1,800,000
Dirtseller Mountain (Collyarton)	30,000	1,000	1.5	h. 25-30 s. 45-55	3,000,000	.....
Shinbone Ridge	6,000 52,800	2,000 3,000	3.3 3.0	h. 30-40 h. 25-35	2,900,000	 31,821,000
Battelle	20,000	2,000	3.3	24-32	8,839,000	.....
Portersville	6,000	2,000	3.3	25-38	2,650,000	.....
Crudup	6,500	1,500	3.5	25-35	2,280,000	.....
Attalla	7,500	2,500	3.5	32-40	5,000,000	.....
Battelle to Attalla	132,500	10,000	3.0	25-30	.....	280,000,000
	.....	.....	.....	.....	86,569,000	440,146,000

[a] Total length of outcrop.
[b] Distance down the dip to which the ore bed may be regarded as workable, either under present or future conditions. Where two distances are given the upper one represents the distance probably workable under present conditions.
[c] Average thickness of the ore bed.
[d] h, Hard ore; s, soft ore.

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THE TAYLOR PEAK AND WHITEPINE IRON-ORE DEPOSITS, COLORADO.

By E. C. HARDER.

INTRODUCTION.

The detailed work on which this report is based was done during the latter part of the summer of 1906 by Freeman Ward and the writer, under the direction of C. K. Leith, who during the summer before, in company with C. R. Van Hise, made a general reconnaissance trip through the region.[a] The Taylor Peak deposits are situated in the Elk Mountains, near the boundary line between Gunnison and Pitkin counties, Colo.; the Whitepine deposits lie about 40 miles to the southeast, in the southeastern part of Gunnison County. Detailed maps of the ore bodies were made, to show their relation to the associated igneous and sedimentary rocks. The deposits consist of igneous contact ores of the same general type as those recently described from the Iron Springs district in Utah,[b] but they are very much smaller than the Iron Springs deposits, and are of no great commercial importance.

The Taylor Peak deposits occur in sedimentary rocks at or near the contact of an intrusive diorite; the Whitepine deposits are at the contact of sediments and Archean granite and are generally associated with small masses of an acidic intrusive.

TAYLOR PEAK DISTRICT.

LOCATION AND GENERAL GEOLOGY.

The Taylor Peak district lies in the eastern part of the Elk Mountains on the boundary between Pitkin and Gunnison counties, Colo. The nearest railway station to the north is Aspen, about 18 miles distant, on the Denver and Rio Grande and Colorado Midland railways, which may be reached by way of Ashcroft. To the south are St. Elmo, Quartz, and Pitkin, about 45 miles distant, on the Colorado and Southern Railway, which may be reached by way of Dorchester and Tincup. The northern part of the district is covered by the Aspen topographic sheet of the survey and the southern part by the

[a] Leith, C. K., Iron ores of the western United States and British Columbia: Bull. U. S. Geol. Survey, No. 285, 1906, p. 196.

[b] Leith, C. K., and Harder, E. C., Iron ores of the Iron Springs district, southern Utah: Bull. U. S. Geol. Survey, No. 338, 1908.

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Crested Butte sheet. In the Anthracite–Crested Butte folio[a] the general geology and petrography of the rocks of the district are adequately discussed. The ore deposits are located on the north, east, and south sides of Taylor Peak, about 10 miles west of the junction of the Elk and Sawatch ranges. They are all above timber line, ranging in elevation between 12,000 and 13,000 feet.

Geologically the district is composed of Cambrian, Silurian, and Carboniferous sediments resting on pre-Cambrian granite and irregularly intruded by a fine-grained diorite of Tertiary age. As given

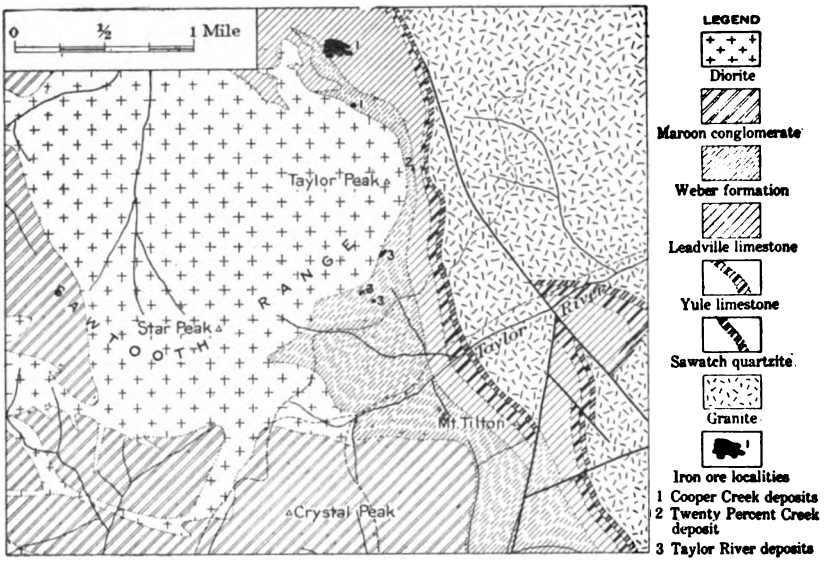

FIGURE 9.—General geologic map of Taylor Peak district, Pitkin and Gunnison counties, Colo., showing location of iron-ore deposits. (From Anthracite–Crested Butte folio, with additions and revisions.)

in the Anthracite–Crested Butte folio the sediments have the following succession:

Carboniferous:

Maroon conglomerate, 4,500 feet. Conglomerate and sandstone, with local limestone layers.

Weber formation, 100 to 550 feet. Dark shale, with limestone layers.

Leadville limestone, 400 to 525 feet. Blue limestone.

Silurian:

Yule limestone, 350 to 450 feet. Limestone with upper shale bed.

Cambrian:

Sawatch quartzite, 50 feet. Quartzite with thin conglomerate at base.

Pre-Cambrian:

Granite, gneiss, and schist.

In general the distribution of formations is as shown in figure 9.

[a] Emmons, S. F., Cross, W., and Eldridge, G. H., Anthracite–Crested Butte folio. Geol. Atlas U. S., folio 9, U. S. Geol. Survey, 1894.

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The pre-Cambrian granite occupies the eastern part of the district and the intrusive diorite the western part; between them is the belt of Paleozoic sediments, the oldest on the east, narrowing to a thin strip on Taylor Peak. The sediments have a general westward dip of 25° to 45°. To the west of the district the diorite is in contact with the Maroon conglomerate, the uppermost Carboniferous formation of this region, but near Taylor Peak it comes into contact with the underlying Weber formation and is very near the Leadville limestone. On account of the proximity of the intrusive rock, the Leadville limestone and the limestone layers in the Weber formation are locally recrystallized and replaced by iron ore.

The Leadville limestone is very coarsely crystalline in places near the diorite contact, showing large cleavage rhombs of calcite. Where it is not so coarsely crystalline it shows numerous needle-like crystals of tremolite. These crystals are especially abundant near chert concretions, around which they form a fibrous matting, due to the presence of abundant silica which has combined with the surrounding lime. Except for the formation of ore deposits the shales of the Weber formation show but slightly the effect of the intrusion. The limestone layers in the Weber, however, have been recrystallized, though not so coarsely as the Leadville limestone. Near the ore deposits both formations are deeply stained by iron.

STRUCTURE OF THE ORE DEPOSITS.

The ore deposits are situated at or near the contact of the sediments with the intrusive diorite, the actual location being determined by the kind of rock and probably by fracturing and faulting. The largest single deposit (fig. 10) lies near the head of Cooper Creek, on the northwest slope of Taylor Peak, about 3½ miles south of Ashcroft. It is located near the contact of the Weber formation and the Leadville limestone, being a replacement of both, and is 500 feet from the diorite contact. This deposit is very irregular, containing horses of quartzite, shale, and limestone and having stringers that extend into the surrounding limestone area. The deposit is situated on a slope of 35° to 45° and is opened by several horizontal tunnels, three of which, having a length of 70, 110, and 120 feet, end in limestone. Whether this limestone is merely a horse or whether it is wall rock is not known, but if it is wall rock a large part of the present body of ore is merely a surface covering. In the limestone area surrounding the deposit there are numerous veins of iron ore and bodies of limestone and shale partly replaced by iron.

The ore is mainly a dark-blue, glossy magnetite with calcite, quartz, pyrite, kaolin, siderite, barite, and chlorite as gangue minerals situated in cavities or disseminated. The gangue minerals are most abundant near the limestone contact. Locally pyrite is present in

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such quantities as to become injurious. In places the ore is soft and friable, but mainly it is dense and hard. Near the surface it becomes more porous, owing to the leaching of gangue minerals, and is stained by limonite. The limonite originates partly from the oxidation and hydration of magnetite, but mainly from the oxidation and hydration of pyrite; indeed, considerable partly altered pyrite is present near the surface.

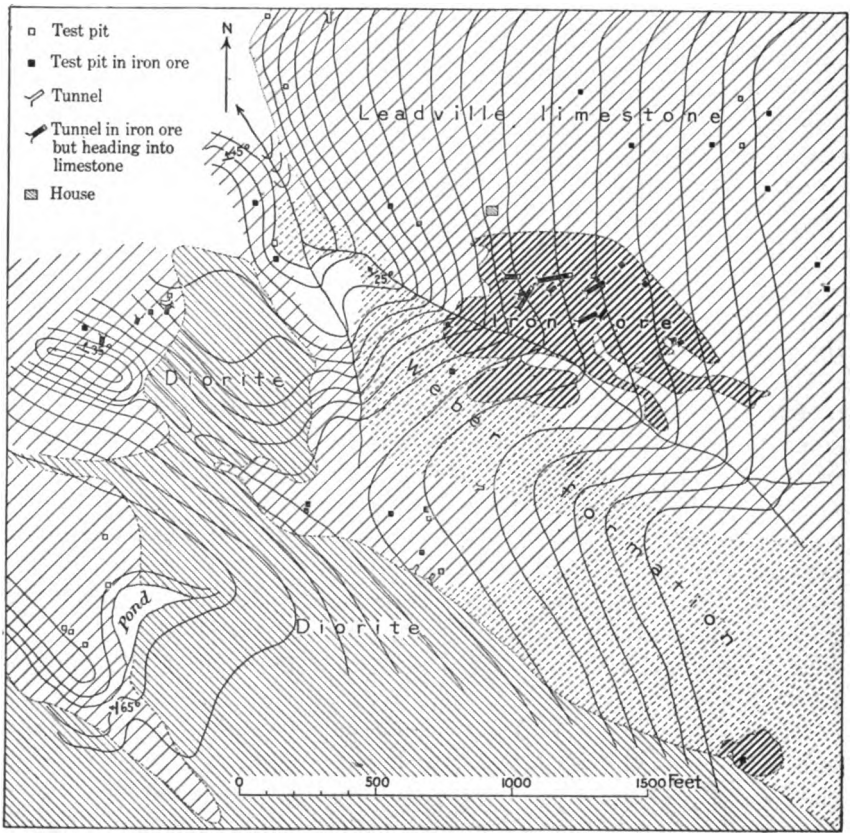

FIGURE 10.—Detailed map of the Copper Creek iron-ore deposits, Taylor Peak district, Colorado.

The contact of iron ore and limestone has commonly a very steep dip—from 70° to 80° toward the iron—but in places the dip is as low as 35°. The limestone is hard and crystalline within a few feet from the contact, and much of it contains veins of calcite. At the contact it is soft and friable and is mixed with gangue minerals and seams of magnetite and limonite. On the iron-ore side of the contact the gangue minerals gradually become less abundant and within a short distance give place to solid magnetite. Near the contact the ore is generally soft, but the main part of the ore body is dense and hard.

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The sediments surrounding the ore deposits contain veins and stringers of iron ore for a distance of several hundred yards, and close to the deposit they are deeply stained and here and there partly replaced by iron.

Halfway between the main deposit and the summit of Taylor Peak is a small deposit at the contact of the diorite and the Weber formation. (See fig. 10.) This deposit contains two kinds of ore—a dense blue magnetite and a mixture of magnetite and limonite with partly replaced sedimentary material. Both kinds are present at the surface; the former probably represents the replacement of a pure limestone, and the latter shows the less thorough replacement of a shaly limestone. The surrounding sediments are stained and partly replaced by iron, but the diorite shows little or no change near the contact. The gangue minerals here are mainly calcite and quartz.

Another small deposit lies at the contact of the diorite and Weber formation on the east side of Taylor Peak, near the head of Twenty Percent Creek. (See fig. 11, *a*.) This deposit is similar in every respect to the one just described, being the replacement of a local limestone area in the shale-limestone formation.

On the southeast slope of Taylor Peak, above Taylor River, there is a series of small deposits in the Weber formation at or near the diorite contact. (See fig. 11, *b*.) The character of the ore here is the same as in the deposits previously described, but the association of gangue minerals differs in some of them. In the deposit farthest to the north, a short distance southeast of the summit of Taylor Peak, the ore is heavily impregnated with chlorite and contains some calcite, and directly at the contact there is an association of pyroxene, amphibole, garnet, epidote, and pyrite in a cherty matrix. The diorite at the contact is finer grained than usual and contains seams and specks of pyrite.

Other deposits of similar character occur along the contact at intervals between Taylor Peak and Star Peak. A few are exposed, but for the most part they are concealed by diorite talus. Several tunnels have been run underneath this talus mantle in search of silver ore and have penetrated limestone and iron-ore deposits. Small amounts of silver and antimony ore also were encountered.

The iron ore is intimately associated with sedimentary material, occurring as local replacements, stains, and small veins. Where the original rock was sandstone or shale the ore is very sandy, some of it being so lean as hardly to be called an iron ore. Most of the deposits, especially the replacement deposits, are very near the diorite contact, but veins of magnetite, limonite, and locally pyrite occur in the sediments at some distance from the igneous rock.

Near Star Peak in the Sawtooth Range the diorite contains included masses of siliceous shales from the Weber formation which have been

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deeply stained and contain little seams of magnetite a few inches in thickness and one or two local areas of ore a few feet in diameter at the contact with the diorite. On account of the color the whole mass has been considered iron ore—the so-called Iron Mountain deposit.

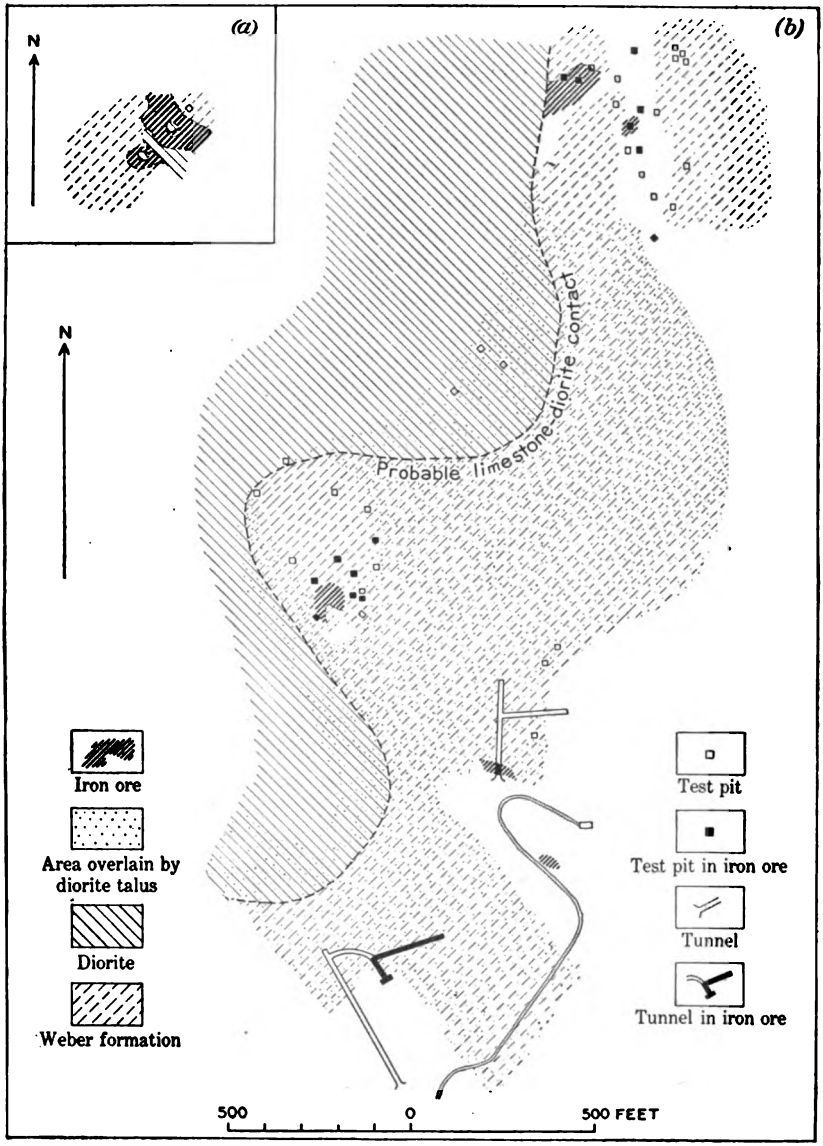

FIGURE 11.—Detailed map of the Twenty Percent Creek (*a*) and Taylor River (*b*) iron-ore deposits, Taylor Peak district, Colorado.

In general, then, the ore follows the diorite contact, replacing the calcareous portions in the adjacent Weber formation or the Leadville limestone where this is close enough. This association shows that the

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ore-bearing solutions were derived from the diorite, and the nature of the gangue minerals shows that they had a deep-seated source.

COMMERCIAL IMPORTANCE.

The iron-ore deposits of the Taylor Peak district are unfortunately situated with regard to topography and railroads. Aspen, the nearest railroad station, is 18 miles north of and 4,000 feet lower than the iron ores. Under great difficulty a branch line might be constructed to a point within a few miles of the Cooper Creek deposits if they were extensive enough to warrant the expenditure, which is not the case. The Taylor River deposits are several miles beyond Cooper Creek, on the other side of the Elk Mountain divide, and would have to be transported by way of Taylor River to the Colorado and Southern Railway. It is practically impossible to construct a railroad nearer than 2 miles from either of these deposits, as they are well up on the slope of the mountains and can hardly be reached by wagon. Unless the price of ore rises so as to make a 15 or 20 mile haul by pack animals and wagon profitable or a cheap method of transportation is installed these deposits will probably not be utilized.

The Cooper Creek deposit is by far the largest in the Taylor Peak district. Measured on the slope (35° SW.) it has an average width of 450 feet north and south and an average length of 750 feet east and west. Three horizontal tunnels have been driven through it into limestone, so apparently a large part of the deposit is merely a surface blanket. With the average depth as shown by the tunnels, the quantity of ore may be estimated as being between 3,000,000 and 4,000,000 tons. Doubtless, however, portions of the deposit go to a much greater depth than the explorations indicate, so that a larger tonnage than that may be expected. All the other deposits should be measured in thousands rather than millions of tons.

Some of the ore contains considerable pyrite, making its sulphur content so high that roasting may be necessary. Locally silicates also are very abundant, especially near the diorite contact, and elsewhere iron has only partly replaced the sediments and the ore contains considerable sand. On the whole, therefore, it is not of very high grade, and this fact, together with the unfortunate location of the deposits, will prevent its utilization for some time to come.

WHITEPINE DISTRICT.

LOCATION AND GENERAL GEOLOGY.

The Whitepine district lies on the west slope of the Sawatch Range, about 10 miles north of Marshall Pass, in the southeastern part of Gunnison County, Colo. It is readily reached from Sargents, on the narrow-gage line of the Denver and Rio Grande Railroad, a dis-

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tance of about 12 miles. The principal deposits lie on the east slope of the valley of Little Tomichi Creek, about half a mile northeast of Whitepine, at an elevation of about 9,500 feet.

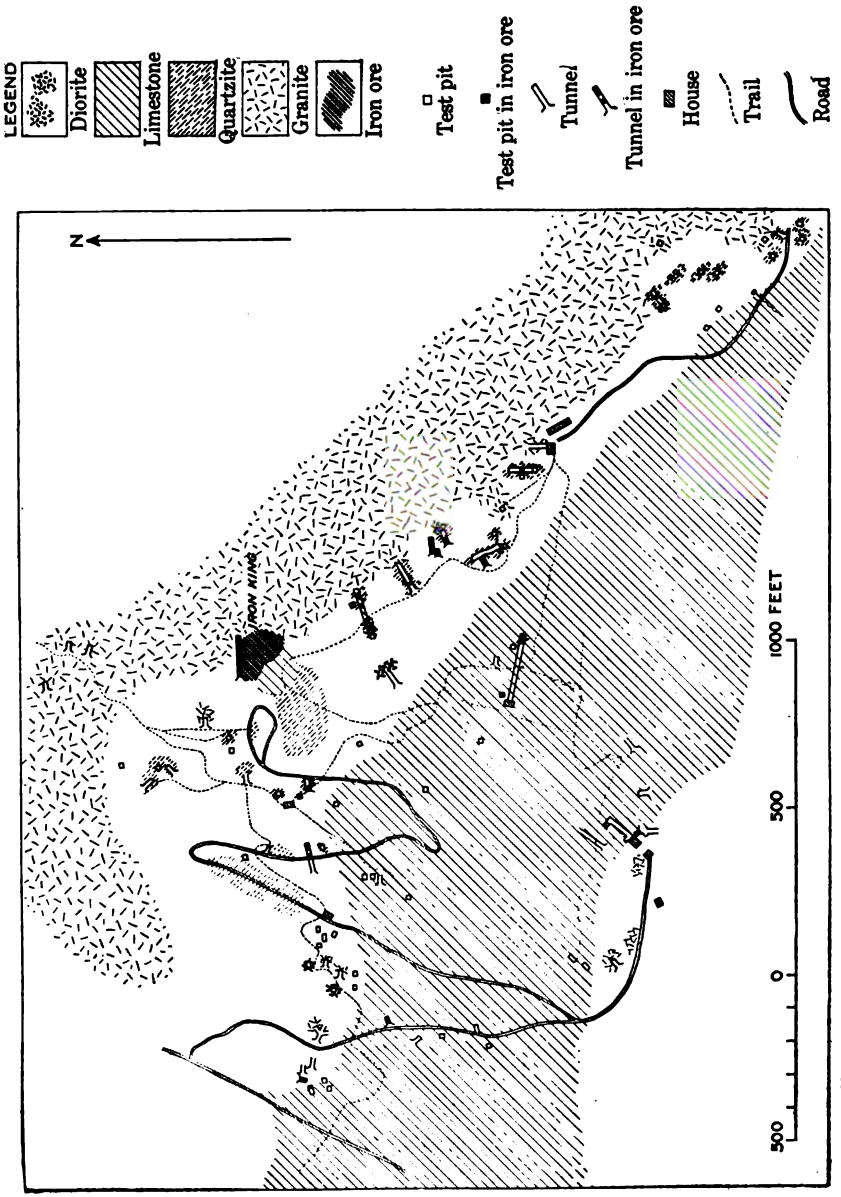

FIGURE 12.—Detailed map of the Whitepine iron-ore deposits, Gunnison county, Colo.

The ore-bearing area has a northwest-southeast trend (see fig. 12), lying along the contact of a granite with shale and limestone. The granite, which is on the northeast and occupies the upper part of the

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slope, is directly connected with the great pre-Cambrian granite mass forming the Sawatch Range. The sediments are presumably Paleozoic, being lithologically very similar to those of the Taylor Peak district. Next to the granite there is generally a layer of vitreous quartzite, of varying thickness up to 30 feet, which may represent the Cambrian. The iron ores occur locally between this quartzite and the overlying rocks. Outside of the quartzite and ores, where these are present, there is a strip of dark-colored limestone and shale, chiefly the latter, and outside of this is a blue or white crystalline limestone, which occupies the lower and principal part of the slope. This limestone is very similar to the Carboniferous limestone of Taylor Peak.

Besides these rocks a light-gray rhyolite is present as an intrusive into the dark shale formation and along the granite contact. It is composed mainly of a light-gray compact groundmass containing phenocrysts of quartz, feldspar, and biotite, the quartz being by far the most abundant. The rhyolite has been intruded in disconnected masses, whose forms could not be determined from the exposures found. The rocks are much fractured and faulted, but the details have not been worked out.

STRUCTURE OF THE ORE DEPOSITS.

The iron-ore deposits of this district are of two kinds—limonitic bog ores and replacement deposits of magnetite and limonite ores. The former occur in a small deposit along Little Tomichi Creek within the granite area, about a mile above the principal deposits. The latter are found in small irregular masses in the limestone-shale formation near the granite contact. In some places only a few feet of vitreous quartzite intervene between ore and granite; in others a mass of rhyolite and layers of the dark limestone-shale formation are present in addition to the quartzite. No place is known where the iron is immediately in contact with the granite. In the Iron King cut, the largest deposit in the district, no quartzite is exposed between ore and granite, but the direct contact can not be seen. As a rule the dip of the contact is steeply toward the iron.

The principal deposits vary in thickness from 5 to 40 feet, and extend along the contact for a distance of several hundred yards. Beyond in either direction is merely a local staining and a few small veins. Ore occurs also in small bodies where the rhyolite has intruded the sediments away from the granite contact, especially where the sediments are limestones, and a few deposits are found in the limestone away from the intrusive masses. The deposits along the granite contact and in association with the rhyolite consist largely of magnetite, but those entirely within the limestone, at some

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distance from the igneous rocks, are composed of dark-brown porous limonite.

The ore associated with the igneous rocks is mainly a glossy, black, compact magnetite with seams and specks of limonite. Locally this ore grades into blue, fine-grained magnetite with chlorite, quartz, and calcite disseminated through it, similar to some of the Taylor Peak ore. In the Iron King cut masses of serpentine and quartzite are interlayered with the magnetite. Large masses of brown ocherous material, which probably represent partial replacements of the limestone-shale formation, occur between the sediments and the ore bodies. This partly replaced border varies in thickness and degree of alteration; in some places it consists merely of stained quartzite, but elsewhere it is soft and friable and contains numerous veins of magnetite, limonite, chlorite, and kaolin. Here and there masses of partly replaced sandstone and shale occur as lenses surrounded by ore or as bands between adjacent ore deposits. The sediments near the ore deposits are heavily impregnated with contact minerals, among which the most conspicuous are epidote, chlorite, amphibole, pyroxene, garnet, pyrite, and magnetite.

From the foregoing statements it is clear that the iron ores are replacements of the calcareous parts of the limestone-shale formation. The nature of the gangue minerals shows the solutions to have had a deep-seated source, but the distribution of the deposits does not show as clearly as the Taylor Peak deposits the nature of this source. The fact that the deposits lie along the granite contact seems to point to the granite as the source, yet that rock is presumably much older than the overlying rocks that contain the ores. The association of the intrusive rhyolite with the granite contact and hence with the ores appears more significant. It is probable that the rhyolite intruded at this horizon, because it was easier of access, on account of the fracturing, and that the ore-bearing solutions were associated with it. Direct evidence for this hypothesis is not everywhere plain, yet the ore bodies and the rhyolite are closely associated and the sediments become altered and iron stained as the intrusive rock is approached.

The limonite ore within the limestone occurs as veins, breccia deposits, and small irregular replacement masses and is clearly of a different type from the contact ores. It was probably deposited by iron-bearing meteoric waters along open channels and replaced the adjoining rocks. The deposits are of small size and of no importance, few of them being more than 15 or 20 feet in diameter.

The bog-ore deposit occurs in the valley bottom along Little Tomichi Creek, about 1½ miles northeast of Whitepine. The granite contact crosses the creek between it and the contact deposits, and the bog ore is a considerable distance within the granite area. The

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deposit is 3 or 4 feet thick and perhaps 2 or 3 rods square and consists of successive layers of ore several inches in thickness. The ore is light and porous and is made up largely of evergreen needles and other vegetation, replaced by limonite.

At several places along Little Tomichi Creek, between this deposit and Whitepine, where the valley bottom is boggy, bog ore is being formed at the present time. This process is especially noticeable below the slope where the contact deposits occur.

COMMERCIAL IMPORTANCE.

So far as present developments show the Whitepine deposits can be considered of but small economic value. They occur in a narrow contact zone, and although they may go to a considerable depth, they are probably too thin to make mining profitable.

The thickness of the deposits varies within short distances. It may be 40 feet at one point and narrow down to 10 feet within a distance of 100 feet. At many places along the contact it pinches out altogether. Moreover, a large proportion of the ore is of low grade, containing clay, sand, silicate minerals, and other impurities.

Transportation facilities are not altogether unfavorable, however, as the narrow-gage line of the Denver and Rio Grande Railroad is only 12 miles distant, and without great difficulty a branch line could be constructed to a point within a short distance of the deposits if their size warranted such an expenditure.

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THE HANOVER IRON-ORE DEPOSITS, NEW MEXICO.

By SIDNEY PAIGE.

INTRODUCTION.

During the latter part of July, 1908, the writer made a rapid reconnaissance of the iron-ore district near Hanover, N. Mex. But a week's time was given to the work and necessarily only the major geologic relations of the field could be studied. Considerable time was spent in the actual tracing of the igneous-sedimentary contact, and attention to those details of petrographic interest which might have been studied by means of systematic collections from the area was impossible. Though copper and zinc are both of economic importance in this district and though their geologic occurrence is intimately associated with that of the iron, time was not available to investigate them and they are not considered in this report.

Two topographic maps including this area have been prepared by the United States Geological Survey; one, the map of the Silver City quadrangle, scale 1:125000, contour interval 100 feet; another, in more detail, the Santa Rita special map, scale 1:24000, contour interval 20 feet. These maps will be ready for general distribution within a few months, and may be obtained for 5 cents each from the Director of the Survey.

Acknowledgment is due to Mr. B. F. Baker, of Hanover, for courtesies extended to the writer.

GEOGRAPHY AND TOPOGRAPHY.

The Hanover district is in Grant County, N. Mex., 12 miles N. 70° E. from Silver City and 2 miles northwest of Santa Rita. It may be reached from Deming, N. Mex., by the Atchison, Topeka and Santa Fe Railway.

The area studied is just within the borders of the mountainous district lying between Gila River on the north, the desert on the south, and Mimbres River on the east. The general elevation of the district is about 6,500 feet, with peaks rising 800 to 2,500 feet higher. The drainage is toward the south, and after passing beyond the mountain border all streams are lost in the desert sands. The district proper is drained by a southward-flowing stream fed by many

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mountain gulches, which in times of heavy rainfalls, such as are characteristic of the region, becomes a raging torrent, carrying in its

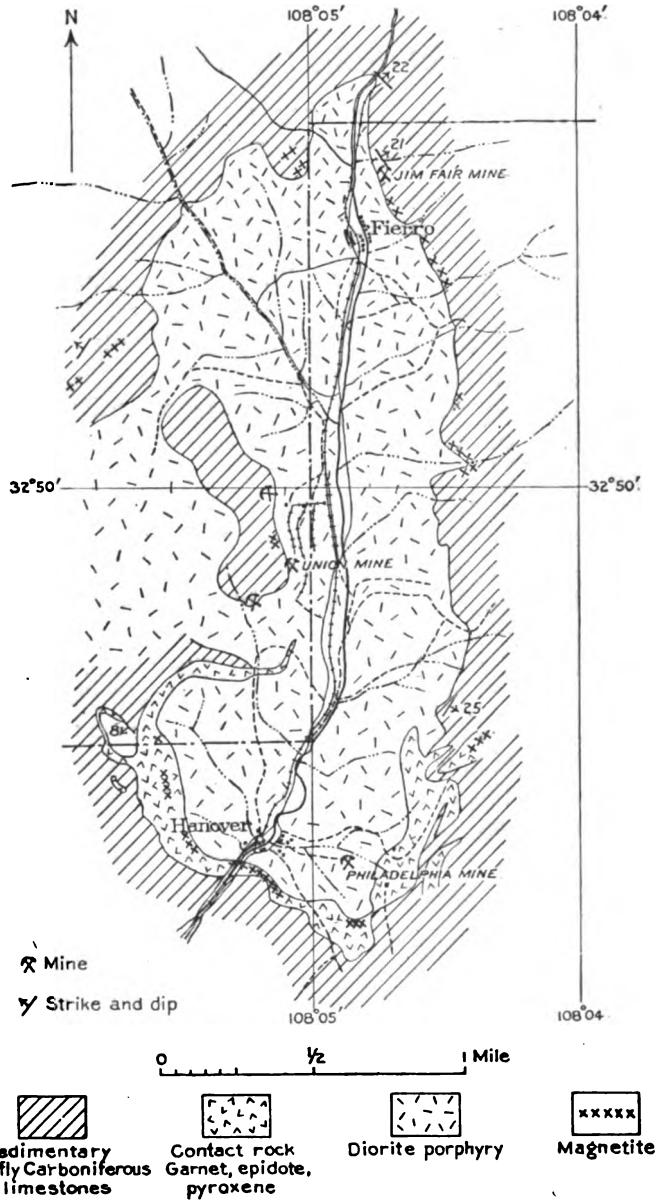

FIGURE 13.—Map showing geologic relations in the Hanover iron-ore district, New Mexico.

waters a large amount of detrital material to be spread out in a great alluvial fan at the edge of the mountains. The general lack of trees and shrubs on the hills facilitates this work of denudation, and

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the region, broadly considered, is a marked example of rapid interior erosion and deposition.

As a geologic unit the district may be described as a narrow basin occupying the upper valley of Hanover Creek, the iron ores being arranged more or less regularly around the edges of an intrusive mass of quartz diorite porphyry. (See fig. 13.) The basin is, roughly, 2½ miles long in a north-south direction and averages three-fourths of a mile in width. On its west side the ores occupy the summits of the ridges; on the east side they are formed along the slopes of a higher ridge. Hanover Creek occupies a central position, flowing southward and exposing in its valley the intrusive quartz diorite porphyry.

GEOLOGY.

GENERAL STATEMENT.

The broad relations of geologic structure in this basin are simple. A mass of quartz diorite porphyry has intruded Carboniferous sedimentary strata, in large part limestone. On a portion of the west side the areal boundaries of the mass are not known. (See fig. 13.) Its general contact determines, at least on the southwest side, the configuration of the hills, which are capped by iron ledge or contact rock. At many localities the determination of bedding is impossible, but so far as could be observed the limestone beds tend to dip away from the mass. In the southern third of the area the intrusive mass has caused extensive metamorphism of the strata. Along this contact zone and also along the contact where metamorphism has been far less pronounced ores of iron, copper, and zinc have been deposited. The iron ore is principally magnetite at one locality with considerable hematite.

At the north end of the area sandstones are present, but their relations to the limestones are not certainly determined; faulting has probably occurred. From the nature of the intrusive mass, the attitude of the surrounding beds, and the prevalence of Carboniferous rocks in the surrounding region it is believed that beds stratigraphically higher than those now exposed formerly extended over the area, or at least buried the present ore deposits under a considerable depth of rock which has been removed by erosion. The isolated mass of limestone on the west side of the area (see fig. 13) and the great thickness of the strata to the east likewise tend to uphold this view.

Where exposed in the larger mines of the district, the contact between the porphyry and the limestone is nearly vertical. However, the manner in which the metamorphism has taken place in the southern portion of the area and the isolated position of the limestone mass surrounded by porphyry on its western border lead to the belief that

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the igneous mass in depth probably has a much greater horizontal extension than is revealed at the surface. This hypothesis is favored by the width of the contact-metamorphic zone, locally as great as 800 feet, excluding narrow bands of contact rock (see fig. 13); the presence of what is believed to be a residual portion of the original cover in the isolated mass on the west side of the area; and the fact that ores of metals other than iron are found at considerable distances from the contact.

SEDIMENTARY ROCKS.

GENERAL CHARACTER.

The prevailing sedimentary rock in the vicinity of the ore deposits is a fine-grained dark-blue limestone of Carboniferous age. Its thickness in this region was not determined. From the evidence derived from float in some of the gulches entering Hanover Creek from the east, it is believed that sandstone beds overlie the limestone, possibly alternating with more limy beds higher in the series. In the northwestern portion of the district siliceous beds were noted underlying limestone, and, still lower, black slaty sediments were observed near the contact. The strike at this point was N. 40° E. and the dip 30° NW. As the limestones are here overlain by a considerable thickness of quartzitic beds, this succession would seem to correspond to that indicated by the float in the creeks on the east side of the basin, where shaly members underlie the limestone. On this side, however, the strike is variably N. 30° W., with a dip of 21° NE. To explain this discrepancy a fault may be assumed to pass northeastward near the eastern base of Hanover Mountain,[a] and the dip of the beds would suggest that if this is the case, the break occurred near the crest of an anticlinal fold.

On the east side of the area, near its south end, shaly beds and in some places limestones are exposed at the base of the series, next to the porphyry contact. These beds strike N. 32° E. and dip 25° SE. The alternation of limestone and shale at the contact may be explained by the irregularity with which the magma intruded the various strata, though it is true that the determination of the original nature of certain beds is complicated by the metamorphism which has taken place within the contact zone. One-half mile northwest of Hanover, in the creek beyond the ridge, the limestone appears to strike N. 45° W. and dip 8° SW. It would seem, then, in general that the sedimentary rocks dip away from the igneous mass and that the doming expressed in their quaquaversal dips is definitely related to the intrusion.

[a] The summit of Hanover Mountain is one-third of a mile northwest of the northern point of the intrusive mass.

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JOINTING AND FAULTING.

Fracturing of the sedimentary rocks is very general, and jointing, sheeting, and faulting have all occurred. Though more extended observation would probably show the prevalence of other directions than those recorded, sufficient data were collected to indicate the general dominance of the lines of breakage. Figure 14 clearly brings out the tendency for joints to form in a northeast-southwest direction and shows the great scarcity of joints in the northwest quadrant. The age of the jointing is difficult to determine, except for the obvious fact that it occurred in large part after the cooling of the intrusive rock. In one place aplite dikelets were observed clearly broken in an east-west direction. Their breakage was sharp, yet the fracture of the diorite porphyry was invisible, even with the aid of a

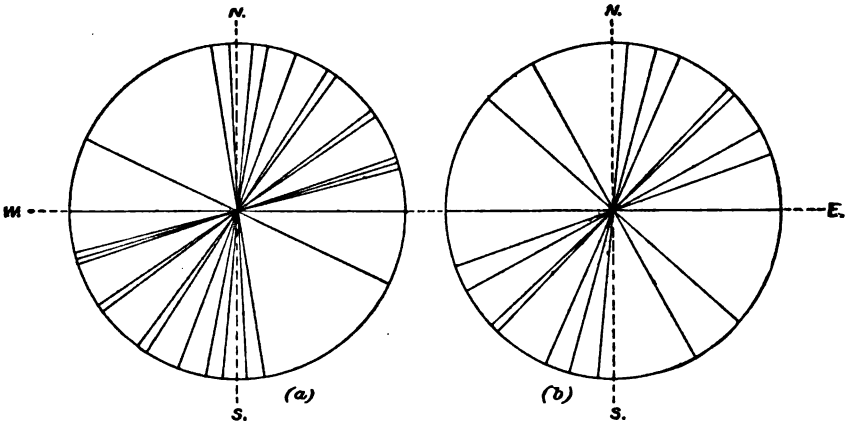

FIGURE 14.—Diagram showing relation of trend of dikes (*b*) to joints and sheeting (*a*) in Hanover iron-ore district, New Mexico.

hand lens. A suggestion that the magma was probably very brittle while still sufficiently hot to undergo recrystallization might explain this condition, for the aplite dike was not disturbed except by a clean fault. Locally pronounced sheeting was observed, trending in north-south and east-west directions. Faulting, except in displacements of very small throw, measured in inches, was observed in only a few localities. In the south pit of the Union mine a fault plane dipping 42° W. and striking nearly north and south can be plainly seen. Its throw is not known, nor is it safe to assume that a considerable movement is involved, for though rock is exposed in the bottom of the pit beneath the ore body its presence is not necessarily an indication of faulting; moreover, a porphyry dike at the north end of the same pit, so far as could be observed, was undisturbed.

On the east side of the area, a little less than a quarter of a mile east of the Philadelphia mine, porphyry dikes have been offset in an

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east-west direction in at least two steps, with a horizontal displacement of 50 and 75 feet. Neither the direction of the actual movement nor that of the fault plane was determined, but it is believed that at least part of the horizontal displacement is due to the dip of the dike on a normal fault.

The postulated fault at the foot of Hanover Mountain mentioned in the preceding section must await further studies for its elucidation, and for the present the suggestion is regarded as purely tentative.

IGNEOUS ROCKS.

MAJOR INTRUSIONS.

The deciphering of variations within igneous masses, the mapping of igneous transitional types, and the theoretical discussion of their origins always require careful detailed work, both in the field and in the laboratory. No such methods could be applied in the present investigation. Sufficient data were obtained, however, to recognize clearly the nature of the main intrusive stock and to note within its mass certain variations. One of these variations is purely textural, to be explained probably by differences in conditions of cooling or location; another is chemical, and for the present its geologic relations must remain unexplained.

The main mass is a quartz-bearing diorite porphyry, and to it or to the immediate results of its intrusion is ascribed the origin of the iron ores. Specimens were collected at various localities within the area and at only two, both in the southeast portion, near the limestone contact, were the rocks other than distinctly porphyritic. At these localities, however, the aspect was clearly that of an abyssal type—in one a quartz-bearing hornblende diorite, in the other a quartz monzonite. Their relation to the porphyritic phase was not determined, but the diorite, because of its definite mineralogical similarity to the porphyry and because of its association, is considered the parent magma. The main stock, the quartz diorite porphyry, must be considered a phase resulting from crystallization under conditions peculiar to the contacts of igneous masses with sedimentary formations. In very general terms such a texture would indicate a position near the top of the mass (in this instance) and this view accords with the hypothesis that the sediments extended over the area at an elevation somewhat near that of the isolated limestone mass on the western border. Megascopically, the quartz diorite porphyry is a light-gray, distinctly granitoid rock. Ferromagnesian minerals are pronounced and give an impression of what would be called a porphyritic diorite. It is only under the microscope, in thin section, that the distinctly porphyritic nature of the type becomes

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clear. The dominant phenocrysts are plagioclase feldspar (ranging from acidic andesine to normal labradorite), biotite, and common green hornblende; Carlsbad and albite twinning is characteristic and zonal growths are numerous. Quartz phenocrysts are of variable occurrence in the several specimens examined, and mica, though not so abundant, is perhaps larger in its development and striking in hand specimens. The groundmass is a microgranitic growth of feldspar and quartz. Magnetite is abundant and titanite, zircon, and some apatite were observed.

The diorite is a holocrystalline, coarse granitoid rock consisting of plagioclase (andesine labradorite), abundant quartz, hornblende, and mica. Augite occurs in small grains and magnetite and titanite are accessory.

The other rock of granitoid texture, whose relations to the main diorite porphyry mass were not determined, may be called a quartz monzonite. The single specimen collected consists of orthoclase, plagioclase, and quartz, in fairly equidimensional development, with ferromagnesian minerals forming a very subordinate part.

To sum up—by far the larger portion of the mass is a quartz-bearing diorite porphyry, within which was found at one locality a true diorite; at another a quartz monzonite. The diorite is regarded as an abyssal parent magma; the relation of the monzonite is not known.

MINOR INTRUSIONS.

As may be seen from figure 14, the dikes of the region are variable in their trend. There is, however, a marked tendency (so far as observations have shown) for their directions to be confined to the northeast and southwest quadrants; and it is possibly significant that the joint systems of the area seem more pronounced along similar lines.

Both granite and diorite porphyries are represented by the dikes, also granite-aplites and some plagioclase-hornblende rocks of diabasic texture.

The granite porphyries are light gray and of variable degrees of fineness. Porphyritic structure is pronounced in some of them, the feldspars attaining a length of three-quarters of an inch. They consist essentially of alkaline feldspar, partly orthoclase, partly plagioclase, with quartz and hornblende. Corrosion of the quartz is marked in one specimen. The feldspars have in several places been greatly altered to sericite and earthy matter. The hornblende commonly alters to chlorite and epidote.

Aplitic dikes of granitic composition are common. In one a granophyric texture was finely developed. This same texture was also observed where chill selvages had been formed along the edges of in-

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truding granite-aplites, which in their main mass were of granular texture. This fact suggests an explanation for the existence of such a texture at a distance from a contact—that is, rapid cooling.

The diorite porphyries are likewise variable in texture and range in color from light to dark gray. One is a dense, dark grayish green, finely crystalline rock with an abundant sprinkling of pyrite. Under the microscope, plagioclase and hornblende phenocrysts are prominent in a groundmass of plagioclase.

A second type of diorite porphyry has a light gray-blue aphanitic groundmass and prominent phenocrysts of plagioclase. In thin section both plagioclase and mica are prominent as phenocrysts and the groundmass is seen to be a microgranitic mass of feldspar and quartz with accessory magnetite.

Two dikes somewhat different from the common examples seen may be described. One consisted of well-crystallized, even grains of plagioclase feldspar. In the hand specimen a green powder between the grains suggested the weathering out of a ferromagnesian mineral, probably hornblende, as this mineral was segregated in bunches in the dike. A little magnetite and titanite were present. This may have been a typical diorite dike. The second dike may be termed a hornblende diabase porphyry—that is, a proterobase porphyry—as, in place of augite, hornblende was present, occupying the interstices between interlocking laths of plagioclase feldspar. Large phenocrysts of hornblende were scattered throughout this mass.

Taken as a group the above-described rocks seem the natural resultants of a period of solidification of the parent magma, when, as openings occurred, magmatic material was thrust into them. Except for the rather abundant occurrence of granite-aplites, there is not much evidence of differentiation into alkalic and ferromagnesian types. It is quite possible that further studies will reveal rocks of a more basic nature, complementary to the aplites. The proterobase porphyry described may be the intrusive accompaniment of certain extensive flows that can be observed a few miles to the south.

Mineralization probably followed or accompanied the intrusion of these more basic types, but it can not be discussed in this report.

METAMORPHISM.

The intrusion of the diorite porphyry mass into the overlying sediments was accompanied or closely followed by intense local metamorphism of the intruded rocks and by less though marked local alteration of the intrusive body itself. This metamorphism was distinctly a contact phenomenon and was definitely confined to the border zone or such localities as are probably near igneous material.

The geologic sketch map (fig. 13) shows clearly that the nature of the metamorphism in different parts of the area was not the same.

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The southern part is especially characterized by a definite border zone, of varying width, occupied by a typical contact rock, in large part epidote, garnet, and pyroxene (augite), with quartz, calcite, pyrite, magnetite, and zinc blende. Though it is hardly safe, in view of the meager amount of time given to the area, to speak definitely of the distribution of these several minerals, the broad fact seems to be clear that magnetite occupies a position at or near the inner border, that garnet and epidote lie next, and that toward the outer edge the pyroxene is most pronounced. Naturally there are transitions, and one or all of these minerals are apt to occur together in any single locality. On the outer edge of the contact zone on the west side the change from pure limestone to pure pyroxene (accompanied by garnet) is markedly abrupt. A knife blade can be placed on the line of demarcation. The limestone seems to have been saturated with a silicate solution which traveled a certain definite distance from the contact beyond which its influence ceased. The pyroxene occurs in crystalline aggregates of radiating augite, in which masses of garnet were seen. Near the contact with the igneous rock a thin section revealed a mass of crystalline epidote, quartz, and some titanite, as a replacement of limestone. The above-described condition is characteristic of that portion which has been mapped as contact rock, though the presence of pyroxene is more pronounced on the western border. Locally the garnet zones are extremely pronounced, the material being composed of large, beautifully crystalline masses of the pure mineral, generally with rhombic dodecahedral development.

Toward the north metamorphism is exhibited in a different manner and may possibly be more dominantly transformative than replacement. Silicification is more pronounced and epidote-garnet zones are rare and only of slight development. The beds nearest the contact, however, show the similarity of the metamorphism to that in the southern part of the area, sedimentary beds of extremely fine texture showing under the microscope crystalline aggregates of epidote and garnet, locally with abundant apatite. On the north some beds that probably were originally shales are composed of extremely fine grains of quartz and feldspar, with an abundant sprinkling of pyrite, and are of the nature of hornfels. On the eastern border, near the center of the area, a distinct banding of the metamorphic minerals is evident, following the stratification of the sediments. Here magnetite, quartz, and abundant apatite were observed, and needles of rutile in the quartz were numerous.

On the northwestern border of the area certain iron bands of considerable thickness are overlain and underlain by rocks representing the more sandy or shaly members of the sedimentary series, and are here cited as a probable example of selective metamorphism—that is, a limy layer has been replaced by magnetite.

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Metamorphism is not confined to the intruded rocks. The diorite porphyry has suffered changes of the same nature as those that have affected the limestones, though to a less degree. Epidote and garnet were noted as contact minerals in the diorite, but the greatest change seemed to be the acquisition of abundant magnetite, probably replacing hornblende, as this mineral was almost entirely lacking in a thin section. There is some evidence also that a finer crystallization has occurred nearer the borders, though this condition is believed to be variable. These points must be left open until further studies can be made. It is known that in some other areas the intrusive rock suffers changes quite as pronounced as those of the rock intruded. In the Velardeña district of Mexico[a] metamorphism was believed to have followed the intrusion and to have been produced by ascending hot solutions that took advantage of fractures in the solidified magma. In the Hanover district evidence is not at hand to prove whether or not this condition existed, and it is presumed that the sediments afforded an easy avenue of escape for circulating solutions, and that these solutions, concentrated along the contact, were more efficient in altering the limestones than they were in replacing the igneous rock.

It is believed from the results of numerous investigations that the important factors determining the nature of the metamorphism due to the contact of igneous masses with sedimentary strata are the chemical composition of the intruded and intrusive rocks, the size of the intrusive mass, the depth at which intrusion took place (a factor that directly affects the pressure and in less degree the temperature), and the condition of the intruded beds with respect to porosity, fracturing, etc. The importance of these several factors has varied in different localities to such an extent that rather diverse views have been put forward respecting their relative weight. The accumulating evidence tends undoubtedly to prove that variable conditions, though it may be difficult to understand their nature, determine the effects of an intrusion. Barrell[b] holds that one of the chief results of his studies is the proof that contact metasomatism is dependent on a temporary permeability of the affected rocks, this permeability being due to a minute fracturing or parting, evidence of which has been in many places nearly destroyed by the metasomatic recrystallization.

He also holds[c] that the siliceous limestones are the strata most readily metamorphosed. This is directly the opposite of what Lind-

[a] Spurr, J. E., and Garrey, G. H., Ore deposits of the Velardeña district, Mexico: Econ. Geology, vol. 3, 1908, p. 698.

[b] Barrell, Joseph, Geology of the Marysville mining district, Montana: Prof. Paper U. S. Geol. Survey No. 57, 1907, p. 117.

[c] Op. cit., p. 147.

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gren[a] finds to be true in the Clifton-Morenci district, Arizona, where the greatest contact effects have been produced in almost pure limestones. Moreover, Lindgren shows[b] that in the main the alteration has no dependence on fissures or veins, and that the only factor which seems to have any influence is the proximity of intrusive bodies.

In regard to volume changes also there are diverse views, but this subject can not be treated here further than to state that in the Hanover district the limestones have received great accessions of iron, sulphur, copper, and zinc, with ferric oxide and silica in the garnet zones.

In summing up, attention may be called to four points. First, the intrusive involved is distinctly a quartzose diorite porphyry and its contact effects have been marked. Second, there is evidence that metamorphism has been selective, the more calcareous sediments suffering the most. Third, evidence of fracturing as an explanation of intense metasomatism is lacking. Fourth, volume changes, if they have taken place, are not observable. It may be added that in those beds which were less susceptible to pneumatolytic changes the alteration has been more in the nature of a recrystallization, with possible siliceous additions. It would seem reasonable to suppose that the purer limestones, as carbon dioxide was driven out, were invaded by magmatic solutions of high temperature, and that any tendency toward shrinkage was overcome by further accessions from the magma. In other words, those elements native to the intruded rock which were of a proper nature to form contact minerals (such as lime and silica) combined with materials from the magma, the whole forming a solution from which the present minerals originated.

IRON ORES.

INTRODUCTION.

The iron ores occurring in the vicinity of Hanover, N. Mex., have been worked since 1899. In 1904 work was suspended because of labor difficulties, but since that time has proceeded nearly continuously.

The principal mines are the Union and the Jim Fair. They are leased by the Colorado Fuel and Iron Company and all the ore is shipped to Pueblo, Colo.

[a] Lindgren, Waldemar, The copper deposits of the Clifton-Morenci district, Arizona: Prof. Paper U. S. Geol. Survey No. 43, 1905, p. 154.

[b] Op. cit., p. 127.

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DISTRIBUTION AND CHARACTER.

The map (fig. 13) shows clearly that the ores are arranged about the periphery of an intrusive stock, at or near its contact with sedimentary beds. With the exception of two localities, one in the northwestern part of the area and the other in the northeastern part (not shown), where the ore deposit is believed to occupy former limestone beds between more siliceous layers, the ore bodies are immediately next to the contact. They are, in the main, irregular lenticular masses of magnetite, in one place partly hematite. Where exposed at the northern and southern pits of the Union mine they are decidedly long as compared with their width and depth. At the Jim Fair mine a shorter, comparatively thicker lens is exposed. All three bodies pinch out in length, and in the northern pit of the Union mine ore has failed in depth. Besides these large bodies numerous outcrops may be observed, indicating the same mode of occurrence; that is, lentils of varying width and thickness, swelling and pinching in horizontal extension and, it may be safely presumed, presenting similar, though uncertain, irregularities in depth.

A second class of ore, which for convenience may be termed "soft ore," likewise occurs along the contact. It is characterized by the disseminated nature of the magnetite, which exists as finely and coarsely crystalline material with a considerable admixture of limestone, and depends for its commercial value on local concentration, whereas the value of the hard ores depends more directly on the size of the deposits and their freedom from impurities. Of the hard ores three bodies have been worked on a large scale, the two pits of the Union mine and the Jim Fair mine (see fig. 13); in the soft ores the principal work has been done immediately south of the southern Union pit, though soft ore, whose commercial value remains to be proved, occurs along the eastern border.

MINERALOGY AND CHEMISTRY.

The principal ore of the region is magnetite, though at the Jim Fair mine considerable hematite has been extracted. Varying amounts of chalcopyrite and zinc blende are associated with the iron ore, but figures are not at hand to express their relation, which is variable. Limestone and contact rock form the most abundant gangue material. In the hard ores the magnetite is generally massive and granular, but the magnetite of the soft ores presents in many places a fine development of crystal form, usually the rhombic dodecahedron.

The following data form part of a report by John Birkinbine on the iron ores of the United States published in 1897.[a] The iron con-

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, pp. 48–50.

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tent shown by these figures probably does not express the facts when the mining operations of several years' duration are considered. A variable content of iron, between 53 and 57 per cent, with lime and silica also variable but correspondingly higher, would probably be nearer correct.

The extract from the report follows:

The following analyses by Messrs. Booth, Garrett, and Blair are of samples taken by Mr. Barringer, each being a sampling across the vein of about 25 pounds in weight. The subsequent shipment of 20,000 or 30,000 tons of ore has verified the correctness of the samples:

Analyses of samples of iron ore taken from the Hanover mines, New Mexico, supplied by D. M. Barringer, M. E.

No.	Metallic iron.	Silica.	Phosphorus.	Character of ore.
	Per cent.	*Per cent.*	*Per cent.*	
1	64.623	3.98	0.021	Specular.
2	63.673	.75	.021	Do.
3	65.979	2.43	.017	Do.
4	65.655	1.16	.028	Specular and magnetic
5	64.258	1.10	.018	Do.
6	65.167	1.33	.017	Do.
7	62.450	.36	.019	Do.
8	64.578	1.20	.028	Do.
9	64.20	.49	.014	Do.
10	67.311	.63	.001	Magnetic.
11	60.132	2.42	.004	Do.

The sulphur determinations have been made in a few instances only, giving an average of 0.041 per cent, but this element is present in such small proportion that it was not considered necessary to have many determinations made. The ore contains no titanium or any other deleterious ingredient. It carries from 0.5 to 1.5 per cent of manganese, some lime, some alumina, and some magnesia, there being rather more of the latter than of lime or alumina. Some of the strictly specular ore, however, contains considerable quantities of lime. Some 4,000 tons of iron ore which were shipped to the Colorado Fuel and Iron Company at Pueblo, Colo., showed the following composition, being the average of 80 carloads:

Analysis of 80 carloads of Hanover, N. Mex., iron ore.

	Per cent.
Iron peroxide	76.00
Iron protoxide	12.85
Phosphoric acid	.041
Titanic acid	Nil.
Manganese oxide	.95
Alumina	.73
Lime	.58
Sulphur	.020
Combined water	2.32
Copper	.085
Iron	63.20
Phosphorus	.018
Silica	4.32
Manganese	.60

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Highest 10 cars, 65.50; lowest 10 cars, 60.05 per cent of iron.

Highest 10 cars, 0.018; lowest 10 cars, 0.015 per cent of phosphorus.

Highest 10 cars, 8.85; lowest 10 cars, 1.65 per cent of silica.

Mr. T. W. Robinson, M. E., of Pueblo, Colo., also made an examination of this deposit, and analyses of samples which he took from nearly all parts of the property are as follows:

Analyses of iron ores from Hanover, N. Mex.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Ferric oxide	72.21	.....	86.00	90.43	81.00	76.07	71.20	69.00	61.86
Ferrous oxide	.....	.....	.....	.....	8.48	11.05	.....	16.07	17.48
Phosphoric acid	.332	.....	.12	.112	.011	.256	.....	.121	.13
Water	10.02	.....	4.24	2.60	3.39	2.62	.....	2.59	.....
Alumina	.78	.....	2.69	2.10	1.95	.75	.....	1.67	.....
Magnesia	1.25	.....	1.06	.05	1.50	.95	.....	6.20	.....
Lime	.37	.....	.40	.84	.15	.16	.....	.31	.....
Peroxide of manganese	2.61	.....	1.26	1.49	.55	2.42	.....	.79	1.07
Silica	12.89	.....	4.36	2.19	2.46	4.74	.....	2.90	.....
Titanium oxide	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Trace.	Trace.
Zinc	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
Copper	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
	100.462	.....	100.13	100.312	99.521	99.016	.....	99.651	80.54
Iron	50.55	54.00	60.20	63.30	63.30	61.85	63.35	60.80	56.90
Phosphorus	.145	.058	.057	.049	.018	.112	.033	.053	.057
Sulphur	.009	.....	.019	.018	.070	.015	.....	.05	.....

GENESIS OF THE ORES.

In view of the foregoing discussion of the probable changes involved in metamorphism but a word is necessary regarding the origin of the ores. Primarily they must be considered as part of the "effects" of the quartz diorite porphyry intrusion. Leith and Harder[a] have shown that in some localities contact metamorphism without much doubt precedes the deposition of magnetite, and that the latter is distinctly an "after effect."

The form of the ore bodies is suggestive. Most of them are irregular lenses occurring at or near the contact. Barrell and others have pointed out the possibility of shrinkage in sedimentary strata due to metamorphism. Leith and Harder,[b] to cite a concrete example, estimate that a horizontal radial shortening of 200 to 500 feet, depending on the depth of the laccolith, was possible as a result of cooling in the Iron Mountain mass. This mass is of the same order of magnetite as the one involved at Hanover. It might be argued, therefore, that lenses, large and small, represent the filling of such shrinkage spaces, and that therefore the magnetite is distinctly an "after effect."

Certain other relations may be significant. For example, where metamorphism is not especially pronounced in the limestones—that is, where zones of garnet, epidote, and pyroxene are lacking—soft ores have formed; in other words, ores which because of their dis-

[a] Leith, C. K., and Harder, E. C., Iron ores of the Iron Springs district, southern Utah: Bull. U. S. Geol. Survey No. 338, 1908, pp. 25–27.

[b] Op. cit., p. 20.

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seminated character and perfect crystallization suggest an emanation of very highly heated solutions of volatile magnetite, precipitated by reduced pressure and temperature. On the other hand, where contact rock occurs these soft ores are lacking. The first inference might be that they were unable to form in such places because of the compact nature of the walls, and the second, that they were, therefore, later than the metamorphism.

Though magnetite filling undoubted fissures in either limestone or porphyry was nowhere noted, at certain localities the magnetite occurs as lenses surrounded entirely by contact rock.

Leaving open, then, for further study the consideration of the precise time relation of the magnetite to the contact metamorphism, we may tentatively suppose the following condition to have existed. On coming to place, the heated magma, by solutions probably above the critical temperature of water, impregnated certain strata of the surrounding rocks. Adjustments, due to cooling of the porphyry, to possible volume changes in the intruded sediments, and to gravity, served to make of the contact zone a favorable locus of superheated gases. Magnetite, a mineral which several investigators have shown might be precipitated from iron silicates by reactions with lime,[a] collected, replacing limestone, filling openings that may have gradually grown, and replacing in part the porphyry mass. The concentration might also be conceived to have been influenced by those laws which regulate the selective growth of mineral masses where abundant material is supplied.

MINING METHODS.

With the exception of some ore extracted recently from the southern part of the Union mine by underground methods, the ore has been mined by open-cut methods. The Union mine is located on a steep hillside and the Jim Fair is sufficiently elevated to permit hauling by gravity. Tunnels in the Union mine and an open cut in the Jim Fair, driven through the contact wall, serve as a roadway for the ore, and trams convey the product to bunkers at the railroad. Mexican labor is used almost exclusively.

STATISTICS.

As was stated in the introduction, mining in the Hanover district has been in progress continuously since 1899, except in 1904 and a part of 1907–8, when labor difficulties closed the mines. Figures segregating the production from the several mines are not at hand, nor are they available for the years 1899 and 1900. The following

[a] Clarke, F. W., The data of geochemistry: Bull. U. S. Geol. Survey No. 330, 1908, p. 283.

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data are found in "Mineral Resources of the United States" for the respective years given:

Production of iron ore from the mines in the Hanover district, New Mexico.

	Long tons.
1901	61,160
1902	132,940
1903	137,843
1904	210,945
1905	113,838
1906	161,555
1907	192,488
	1,010,779

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THE IRON ORES OF THE APPALACHIAN REGION IN VIRGINIA.

By E. C. HARDER.

INTRODUCTION.

The work of the United States Geological Survey on the iron ores of Virginia was begun in 1905 by E. C. Eckel, assisted by R. J. Holden and J. S. Grasty, with a survey of the Oriskany ores of western Virginia and the "mountain" and "valley" ores of the New River district. Subsequently the work was discontinued for several years, but was recommenced in the fall of 1908 by the writer, with a detailed examination of the ores of the Blue Ridge and a general reconnaissance of the Oriskany ores and the ores of the New River district.

Preliminary reports of the former surveys were published in 1906,[a] and the present paper will be a general summary of the results so far obtained. It is expected that a more detailed report on the brown ores of the entire Appalachian province will be published in the future.

IRON ORES OF VIRGINIA.

CLASSES AND DISTRIBUTION.

Iron ores and minerals of three types—hematite, magnetite, and brown ore—play an important part in the iron industry of Virginia. Iron carbonate and sulphide occur at many places, but are of no great commercial importance. The iron-ore deposits of Virginia may be separated geographically into two groups—those of the Piedmont region and those of the Appalachian region. The ores of the Piedmont region occur in pre-Cambrian crystalline and metamorphic rocks; those of the Appalachian region occur in Paleozoic sediments

[a] Eckel, E. C., The Oriskany and Clinton ores of Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 183. Holden, R. J., The brown ores of the New River-Cripple Creek district, Virginia: Idem, p. 190.

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or residual material derived from them. Both of these groups contain ores of several types, which may be classified as follows (see fig. 15):

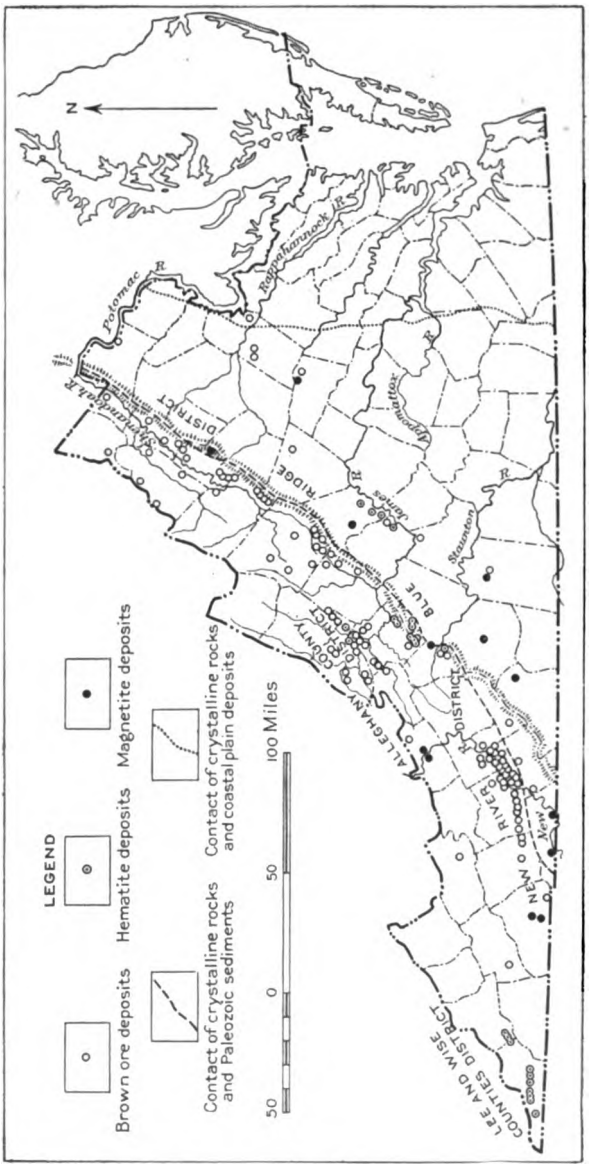

FIGURE 15.—Map showing the distribution of various classes of iron ores in Virginia.

Piedmont region:

1. Hematite. Specular hematite associated with nontitaniferous magnetite in the James River valley.
2. Brown ore. Gossan ore forming a capping of pyrrhotite deposits in southwestern Virginia and pyrite deposits in northern and central Virginia.

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Piedmont region—Continued.

3. Magnetite—
   a. Nontitaniferous magnetite associated with gneisses, schists, and crystalline limestones in central and southwestern Virginia.
   b. Titaniferous magnetite associated with basic intrusives in the Blue Ridge.
4. Iron sulphides. Pyrite and pyrrhotite, used largely in the manufacture of sulphuric acid, the waste product (iron oxide or "blue billy") being used for its iron.

Appalachian region:

1. Hematite—
   a. Siliceous specular hematite interbedded with lower Cambrian shale and quartzite in the Blue Ridge.
   b. Fossil hematite interbedded with shale and sandstone of Clinton (Rockwood) formation in western and southwestern Virginia.
2. Brown ore—
   a. "Mountain" ores of the Blue Ridge and of the New River district, associated with lower Cambrian quartzite and with residual material above it derived from the quartzite and from the overlying formations.
   b. "Valley" ores associated with residual material of the Shady limestone in the New River district. A few deposits of this nature occur with other limestones of the Shenandoah group along the Blue Ridge.
   c. Oriskany ores replacing the Lewistown limestone directly underneath the "Monterey" (Oriskany) sandstone in the western part of the Appalachian region.
3. Magnetite. Magnetite and hematite associated with limonite and iron carbonate in the upper part of the Shenandoah group locally in southwestern Virginia.
4. Iron carbonate. Iron carbonate occurring with limestone magnetite in the upper part of the Shenandoah group locally in southwestern Virginia and as ironstone concretions in the Martinsburg and Romney shales.
5. Iron sulphide. Pyrite found locally in the Shady limestone in southwestern Virginia and used in the manufacture of sulphuric acid. The waste product, iron oxide or "blue billy," is used in blast furnaces for the manufacture of pig iron.

IRON ORES OF THE PIEDMONT REGION.

The iron ores of the Piedmont region are not of very much importance commercially, though small quantities of brown ore and magnetite are produced annually. The brown ore is derived from the upper portion of pyrrhotite veins; the magnetite is of the nontitaniferous variety and is associated with schists and crystalline limestone. None of the other ores are being produced at present except sulphides, which are used in the manufacture of sulphuric acid.

Specular hematite[a] and martite occur in crystalline schist in the James River valley, associated with nontitaniferous magnetite. In some places these two types are intermixed; elsewhere they occur in

[a] Benton, E. R., Iron mines of Virginia: Tenth Census, vol. 15, Mining industries, 1886, p. 263.

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separate deposits. They are found in association with mica and talc schists, quartzite, and limestone. The following table gives analyses of specular hematite:

Analyses of specular hematite (natural state) from the James River valley.[a]
[By F. A. Gooch.]

	1.	2.	3.	4.
Fe	53.02	40.51	48.92	49.89
P	.049	.095	.033	0.139

1. Greenway mine, near Greenway, Nelson County.
2. Adams, Scott & Co., mine No. 11, near Riverville, Amherst County.
3. Naylor & Co., mine No. 6½, near Riverville, Amherst County.
4. Maud vein, near Stapleton, Amherst County.

Pyrrhotite and pyrite gossan consisting of limonite resulting from the oxidation of the sulphides is widely distributed through the Piedmont region. Pyrite gossan[b] formed the basis for the first iron industry in Virginia, but it has not been mined for a long time. It is found in the pre-Cambrian schists in many places east of the Blue Ridge, occurring in the upper oxidized portion of the pyrite lodes. Pyrrhotite gossan[b] occurs in southern and southwestern Virginia as a capping of the pyrrhotite lodes in crystalline schists. The principal deposits are in Grayson, Carroll, Floyd, and Franklin counties. The lodes are more or less continuous and dip with the schistosity of the rocks—about 35° SE. Locally they are workable for a distance of several miles, and in many places they have a constant width of 10 to 20 feet for several hundred yards. The maximum width of the lodes is about 175 feet. The gossan grades below into pyrrhotite associated with chalcopyrite, talc, calcite, hornblende, and quartz. The weathered portion extends to a depth of 10 to 60 feet, and consists of porous light-brown or yellow limonite. The lodes are frequently mined for copper, which generally occurs as black oxide at the junction of the gossan and the unweathered pyrrhotite.

The following table gives analyses of gossan ore.

Analyses of Virginia gossan ore.[c]

	1.	2.	3.	4.
Fe	44.54	42.81	36.15	47.00
SiO_2			16.36	12.25
P	.850	.478	.12	.85
Mn			1.40	2.70

1. Brown hematite mine, near Old Elk Creek furnace, Amherst County. Analysis by F. A. Gooch.
2. Stonewall mine, near Stapleton, Amherst County. Analysis by F. A. Gooch.
3. Betty Baker mine, near Betty Baker, Carroll County. Analysis by Virginia Iron, Coal and Coke Co.
4. Barr limonite mine, near Pittsville, Pittsylvania County. Analysis from J. H. C. Barr.

Nontitaniferous magnetite[d] is widely distributed through the crystalline schist of the Piedmont region, but occurs most abundantly in

[a] Benton, E. R., op. cit., pp. 264, 265, 268.
[b] Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, p. 419.
[c] Analyses 1 and 2 from Benton, E. R., op. cit., pp. 474, 476; 3 and 4 from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, pp. 265, 269.
[d] Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, p. 421.

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the James River valley northeast of Lynchburg, near Pittsville in Pittsylvania County, and in Franklin and Patrick counties. The James River valley area was the principal iron-producing district in the State a hundred years ago, and was again exploited in 1880. Specular hematite constitutes most of the ore, but magnetite is associated with it. Near Pittsville the ore is magnetite and occurs as a lode between crystalline limestone and mica schist having a maximum thickness of 12 feet. In Franklin and Patrick counties magnetite occurs in hornblende schist in lodes varying up to 12 feet in thickness.

The following table gives analyses of nontitaniferous magnetite:

Analyses of Virginia nontitaniferous magnetite.[a]

	1.	2.	3.	4.	5.	6.
Fe	44.96	38.43	59.83	64.25	53.59	59.98
SiO_2				4.52	14.67	7.72
P	.051	.118	.086	.008	.018	.08
Mn						.17
S					.364	.19

1. Adams, Scott & Co., mine No. 13, near Riverville, Amherst County. Analysis by F. A. Gooch (specular hematite and magnetite).
2. First vein east of Old Furnace vein, near Old Elk Creek furnace, Amherst County. Analysis by F. A. Gooch (specular hematite and magnetite).
3. Pittsville mine, near Pittsville, Pittsylvania County. Analysis by F. A. Gooch.
4. Barr magnetite mine, near Pittsville, Pittsylvania County. Analysis from J. H. C. Barr.
5. Rocky Mount mine, near Rocky Mount, Franklin County. Analysis by F. A. Gooch.
6. Hairston mine, near Philpot, Patrick County. Sampled by W. W. Davis.

Titaniferous magnetite occurs at several localities in the Blue Ridge region in different associations. About 3 miles southeast of Marksville, Page County, it occurs as small bodies segregated locally in a basic syenite (unakite).[b] The ore contains considerable foreign material, mostly minerals common in the inclosing rock. These are generally in the form of rounded specks and vary in abundance in different parts of the deposit. Similar ore is reported from other places along the Blue Ridge. Near Roseland, Nelson County, and near Vinton, Roanoke County, ore of this type occurs with different associations. It consists of a mixture of ilmenite and apatite[c] and occurs in the form of a dike cutting the inclosing rocks. In Nelson County it occurs in schists and gneisses; in Roanoke County it is near the contact of gneisses with Cambrian sediments.

The following is an analysis of titaniferous magnetite:

Analysis of titaniferous magnetite from Marksville, Va.[d]

[By Booth, Garrett & Blair.]

Fe	51.44
TiO_2	16.76
P	.97

[a] Analyses 1, 2, 3, and 5 from Benton, E. R., op. cit., pp. 265, 266, 270, 273; 4 and 6 from Holden, R. J., op. cit., pp. 473, 475. All but 4 in the natural state.
[b] Phalen, W. C., Copper deposits near Luray, Va.: Bull. U. S. Geol. Survey No. 285, 1906, pp. 140–143.
[c] Watson, T. L., Phosphates, in Mineral resources of Virginia, 1907, pp. 300–302.
[d] Holden, R. J., op. cit., p. 433.

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Pyrite and pyrrhotite occurring in the unoxidized portions of deposits described with reference to gossan ores are mined in a few places for the manufacture of sulphuric acid. After roasting out the sulphur the residue is in the form of a cinder consisting of iron oxide with 4 to 7 per cent of sulphur.[a] This is clinkered in kilns and the resulting product contains 52 to 56 per cent of iron and 0.05 per cent of sulphur, as compared with 45 to 52 per cent of iron and 27 to 32 per cent of sulphur in the crude ore. It is mixed with iron ore and used by iron blast furnaces.

IRON ORES OF THE APPALACHIAN REGION.

GENERAL STATEMENT.

By far the most important iron ores in Virginia are the brown ores of the Appalachian region, including "mountain," "valley," and Oriskany ores, and of them the Oriskany ores form the principal part. Second in importance are the specular hematites of the Blue Ridge, and, third, the Clinton fossil ores. The remaining types are of minor importance.

The mountain and valley brown ores of Virginia form part of a continuous belt of these ores extending from Vermont to Alabama. The Oriskany ores are confined largely to Virginia and West Virginia, though ores are found locally at this horizon in Kentucky and Pennsylvania. The specular hematite of the Blue Ridge belongs to the same class and occurs at approximately the same horizon as the specular or gray ores of Georgia and Alabama. The fossil ore belongs to the general type of Clinton ores found in the Birmingham and Chattanooga districts and in New York.

The rocks of western Virginia range in age from pre-Cambrian to Pennsylvanian. The former compose the eastern part of the Blue Ridge and extend eastward, and the latter cap the Allegheny escarpment and extend westward. The Appalachian Valley occupies a northeast-southwest belt between these boundaries and contains rocks ranging in age from Cambrian to Mississippian. The areal distribution of the rocks of the valley is very irregular, owing to the great amount of folding and thrust faulting. In general, however, the formations occupy discontinuous northeast-southwest strips, the older rocks being more abundant on the east side and the younger on the west side of the valley. The following sections show the latest classification of the rocks for the Appalachian region in Virginia:

[a] Iron and zinc deposits in southwestern Virginia: Eng. and Min. Jour., Nov. 7, 1908, p. 908.

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Geologic sections for the Appalachian region in Virginia.[a]

Northwestern Virginia.		West-central Virginia.		Southwestern Virginia.	
Formation.	Thickness (feet).	Formation.	Thickness (feet).	Formation.	Thickness (feet).
Mississippian:		Mississippian:		Mississippian:	
Greenbrier limestone	325– 410	Pocono sandstone	700	Pennington shale	1,250–1,350
Pocono sandstone	85– 700			Newman or Greenbrier limestone	1,500
				Pulaski shale	0– 300
				Price sandstone	0– 300
Devonian:		Devonian:		Devonian:	
Hampshire formation	1,600–2,200	Hampshire formation	1,000–1,400	Grainger shale	1,000–1,500
Jennings formation	2,100–3,800	Jennings formation	2,800–3,400	Chattanooga shale	400– 800
Romney shale	1,000–1,300	Romney shale	600–1,000		
Silurian:		Silurian:		Silurian:	
"Monterey" (Oriskany) sandstone	200– 300	"Monterey" (Oriskany) sandstone	0– 300	Giles formation	30– 200
Lewistown limestone	700–1,250	Lewistown limestone	300– 500	Clinton (Rockwood) formation	20– 400
Clinton (Rockwood) formation	65– 550	Clinton (Rockwood) formation	120– 500	Clinch sandstone	100– 250
Cacapon sandstone	200– 350	Massanutten sandstone	500– 600		
Tuscarora quartzite	300±				
Ordovician:		Ordovician:		Ordovician:	
Juniata sandstone	200±	Massanutten sandstone		Bays sandstone	250– 350
Martinsburg shale	1,600–1,800±	Martinsburg shale	800–1,400	Sevier shale	1,250–1,350
Chambersburg limestone (Shenandoah group.)	400	Liberty Hall limestone (Shenandoah group.)	1,000±	Moccasin limestone, 0–400 feet; Tellico sandstone, 300 feet	0– 400
Stones River limestone (Shenandoah group.)	900	Murat limestone (Shenandoah group.)	100– 150	Chickamauga limestone, 0–1,000 feet; Athens shale, 300–1,200 feet	0–1,200
Undifferentiated Shenandoah (Shenandoah group.)	1,200–1,500	Natural Bridge limestone (Shenandoah group.)	3,500	Holston marble lentil	0– 190
				Knox dolomite	100–2,400
Cambrian:		Cambrian:		Cambrian:	
Undifferentiated Shenandoah (Sequence broken.)		Natural Bridge limestone		Knox dolomite	
Antietam sandstone	500	"Buena Vista" shale	600– 900	Nolichucky shale	0– 175
Harpers shale	1,000+	Sherwood limestone	1,600–1,800	Honaker limestone	900–1,000
Weverton sandstone	100– 900	Lower Cambrian quartzite	800	Watauga shale	1,000–1,100
Loudoun formation	0– 800	Lower Cambrian shale and quartzite	3,000	Shady limestone	750– 800
				Erwin quartzite	500– 700
				Hampton shale	600– 800
				Unicoi sandstone	1,500–2,500
Algonkian:		Pre-Cambrian:		Pre-Cambrian:	
Catoctin schist	1,000+	Crystalline and metamorphic rocks.		Crystalline and metamorphic rocks.	

[a] Bassler, R. S., Cement materials of western Virginia: Econ. Geology, vol. 3, No. 6, 1908, p. 510. Campbell, H. D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Am. Jour. Sci., 4th ser., vol. 20, 1905, p. 445. Keith, Arthur, Geol. Atlas U. S., folios 10 (Harpers Ferry) and 90 (Cranberry). Darton, N. H., Geol. Atlas U. S., folios 14 (Staunton), 32 (Franklin), and 61 (Monterey). Campbell, M. R., Geol. Atlas U. S., folios 26 (Pocahontas), 44 (Tazewell), and 59 (Bristol).

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The iron ores are distributed through the Cambrian, Ordovician, and Silurian rocks, as shown in the accompanying general section (fig. 16). The lowest ore stratigraphically is the siliceous specular hematite of the Blue Ridge. It is associated with the lower Cambrian shale and quartzite shown in the west-central Virginia section, but in what part of this series it occurs is not definitely known. Next above it is the mountain brown ore. Along the Blue Ridge this ore is found in pockets in residual material along the contact of the lower Cambrian quartzite and the overlying formations, and as fault deposits and replacements in the quartzite. Several formations come into contact with the quartzite at different places along the Blue Ridge on account of extensive faulting. In the New River district mountain ores occur in residual material along the contact of the Erwin quartzite and the overlying Shady limestone. Locally, mountain brown ores are known to occur in Tertiary or Pleistocene variegated clays associated with the residual clay mentioned above. The valley brown ore is found mainly in the New River district in residual clay derived from the Shady limestone. In the Blue Ridge region small, scattered deposits occur in residual material overlying the Natural Bridge limestone. All the valley ores rest on an eroded limestone surface. The pyrite deposits are associated with the Shady limestone.

The upper part of the Shenandoah group contains limestone magnetites with associated limonite and carbonate. These ores occur in limestone and in residual clays derived from it. Their exact stratigraphic position has not been determined, but it is probably at the horizon of the Chickamauga limestone.

The fossil ore beds occur in the Clinton (Rockwood) formation, interbedded with shales. The Oriskany iron ores are found at the horizon of the Lewistown limestone, occurring as a replacement of the upper portion of this limestone directly underneath the "Monterey" (Oriskany) sandstone.

The following analyses are typical of the various classes of ores:

Analyses of type specimens of various classes of Virginia iron ores.

[By Lerch Brothers, Virginia, Minn. Determination at 100° C. (212° F.).]

	1.	2.	3.	4.	5.	6.	7.	8.
Fe	44.00	56.70	49.18	53.86	59.81	32.59	56.12	53.75
P	.465	.428	.376	.958	.081	.068	.095	.191
Mn	.....	.....	.32	.27	.61	.12	.14	.57
SiO_2	29.90	6.83	13.73	6.83	3.06	45.24	6.46	10.31
Al_2O_3	2.73	.....	.....	.....	.....	6.30	.....	.....
CaO	.....	.12	.....	.....	.....	.....	.....	.....
Loss by ignition (largely H_2O)	.....	.....	10.33	10.45	10.78	.....	11.55	10.48

1. Siliceous specular hematite, Arcadia mine, near Buchanan, Botetourt County.
2. Clinton fossil hematite, Horse Mountain mine, near Low Moor, Alleghany County.
3. Earthy mountain brown ore, Bare Bank mine, near Greenville, Augusta County.
4. Black glossy mountain brown ore, Dixie mine, near Vesuvius, Rockbridge County.
5. Needle mountain brown ore, Mine Bank mine, in Augusta County, near Vesuvius.
6. Red shaly mountain brown ore, Buena Vista mine, near Buena Vista, Rockbridge County.
7. Valley brown ore, Buck Hill mine, near Midvale, Rockbridge County.
8. Oriskany brown ore, Rich Patch mine, near Low Moor, Alleghany County.

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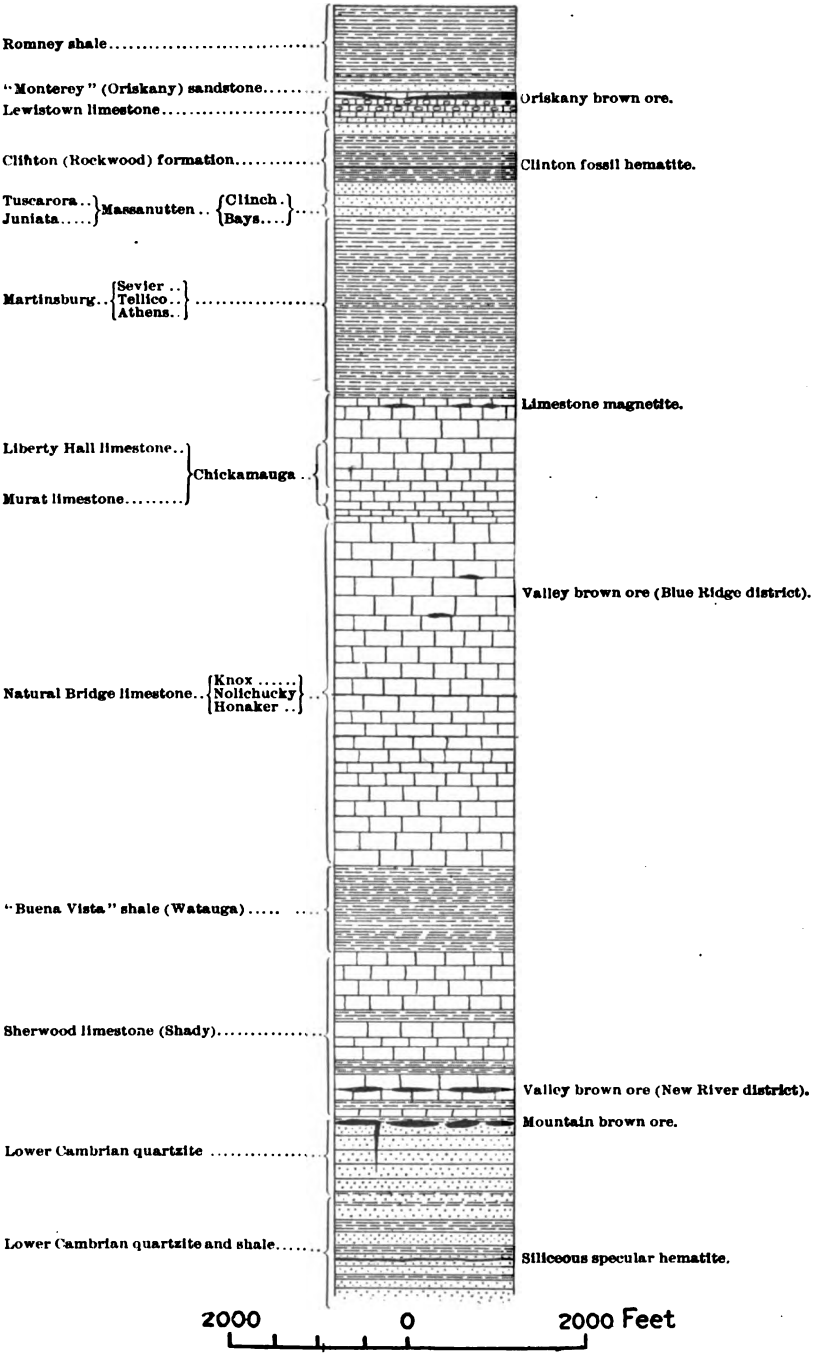

FIGURE 16.—Generalized section showing the stratigraphic position of the various classes of iron ore in the Appalachian region of Virginia.

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Analyses 1 and 2 represent hematite (Fe_2O_3; theoretical percentage of iron, 70); the rest represent hydrous oxides consisting of various mixtures of limonite ($2Fe_2O_3.3H_2O$; theoretical percentage of iron, 59.8) and göthite ($Fe_2O_3.H_2O$; theoretical percentage of iron, 62.9). Turgite ($2Fe_2O_3.H_2O$) may be present in small quantities, but for the most part the ores contain too much water to make its presence seem likely.

In the following table are given the iron and water content of limonite, göthite, and turgite and of the five typical brown ores represented by analyses 3, 4, 5, 7, and 8, above. Specimen 6 is not a typical ore, but simply a partial replacement product. As the above determinations were made in a commercial laboratory, it was impracticable to obtain the combined water. The carbonaceous material present is so small, however, and the amount of moisture so slight that for practical purposes the loss by ignition may be regarded as combined water.

Percentage of iron and water and ratio of iron to water in hydrous iron oxides and brown ores.

	Percentages.		Ratio of iron to water.
	Iron.	Water.	
Limonite	59.8	14.5	4.12:1
Göthite	62.9	10.1	6.23:1
Turgite[a]	66.0	6.0	11.00:1
Earthy mountain ore (3)	49.18	10.33	4.76:1
Glossy black mountain ore (4)	53.86	10.45	5.15:1
Needle ore (5)	59.81	10.78	5.55:1
Valley ore (7)	56.12	11.55	4.86:1
Oriskany ore (8)	53.75	10.48	5.13:1

[a] The composition and ratio for turgite are only approximate.

From this table it is apparent that the ores are intermediate in composition between limonite and göthite and that they vary from three-fourths limonite and one-fourth göthite to one-fourth limonite and three-fourths göthite. The needle ore, which is the purest variety, is most nearly like göthite in composition. The valley ore, which contains considerable ocher, is more nearly like limonite in composition. All the brown-ore analyses show a decided difference from that of turgite, so it may be concluded that this mineral, if present in the mixture, is negligible.

SILICEOUS SPECULAR HEMATITE.

Location and geology.—The specular hematite of Virginia occurs interlayered with the lower Cambrian quartzite and shale as a bed of varying thickness. Workable portions of it outcrop along the Blue Ridge in Botetourt, Bedford, and Roanoke counties, from Buchanan on the north to a point about 5 miles south of Roanoke.

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North of Buchanan the bed changes gradually to a ferruginous sandstone, and as such has been found west of Buena Vista, and is reported as far north as Basic City. Southward from the main outcrop it apparently loses its identity.

The associated rocks are Cambrian shale, sandstone, and quartzite in beds having a general northeast-southwest strike. The dip is variable, being about 50° SE. near Buchanan and 30° NW. near Blue Ridge Springs. Near the surface the rocks are considerably weathered and have a yellow, brown, or gray color. In depth they are hard and quartzitic and their color is dark green.

Ore bed.—The ore bed has been worked at eight localities along its principal outcrops. The distribution of the mines is as follows, from northeast to southwest: The Arcadia and Wood mines, about 4 miles southeast of Buchanan; the Ironville and Dewey mines, near Montvale; the Lemon, Grubb-Specular, and Edith mines, about 3 miles northwest of Blue Ridge Springs; and the Griffin-Specular mine, about 5 miles south of Roanoke. Of these the Arcadia, Wood, Dewey, and Edith mines are at present in operation.

Between the mines near Buchanan and those near Montvale there is a distance of 6 miles in which the bed has hardly been exploited, but through a considerable portion of which it is known to exist. Between the mines near Montvale and those near Blue Ridge Springs there is apparently an offset in the bed, and southwest of the latter place it disappears for a distance of 12 or 15 miles, reappearing at the Griffin-Specular mine.

At the Arcadia and Wood mines the ore bed is well up on the northwest slope of the Blue Ridge, being at an elevation of about 2,000 feet above sea level, or 1,000 feet above the valley to the west. The lower portion of the slope and the valley are formed by lower Cambrian quartzite, Sherwood limestone, and "Buena Vista" shale. The ore bed apparently continues at this elevation and on this slope of the Blue Ridge for several miles to the southwest to a point where it crosses over to the southeast slope and probably connects with the exposures at Montvale or Blue Ridge Springs. Nothing definite is known about its location in this intervening area.

At the northernmost mines the ore occurs in two beds, an upper one having an average thickness of 4½ feet and a lower one having a thickness of about 6 inches. (See fig. 17.) These beds are separated from each other by a 6-inch bed of yellowish or greenish brown fine-grained sandstone. The upper bed varies in thickness from 3½ to 6 feet, but the thickness of the lower bed is fairly uniform. Only the upper bed is mined, the lower one being too thin to pay for the removal of the intervening sandstone layer. The beds have a general strike of N. 40° E. and an average dip of 50° SE. Near the surface

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they are locally almost vertical and in some places even dip to the northwest.

The Arcadia mine is at present working the ore bed on its most northerly workable outcrop, and the Wood mine adjoins it on the south. On both properties the bed has suffered some folding and a great deal of faulting, so that locally, especially at its north end, there are two or three parallel outcrops within a distance of less than 100 yards. At the north end of the present workings of the Arcadia mine a ravine cuts across the strike of the strata and here the ore bed was found to end abruptly. Recent exploration has succeeded in revealing the presence of the bed about half a mile to the northwest and operations have begun along this extension, which is said to have the same strike and dip as the bed at the present workings. The old workings of the Arcadia mine and the operations of the Wood mine extend along the outcrop of the bed for a distance of nearly a mile.

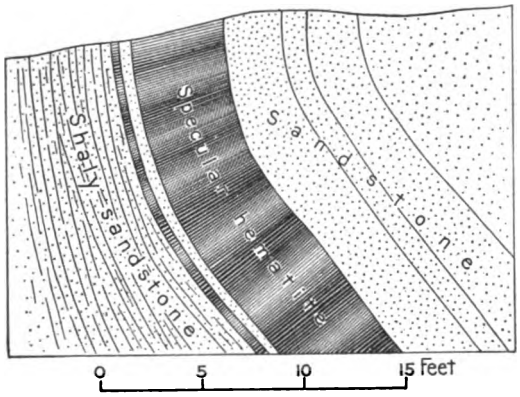

FIGURE 17.—Vertical section showing the structure and position of the specular hematite beds at the Arcadia mine, near Buchanan, Va.

The ore consists of dark-red, very siliceous hematite, the silica being present in the form of sand grains. Locally the ore contains small quartz pebbles or small balls of clay, called "frog eyes" by the miners; but as a rule the bed has a uniform texture throughout. The lower ore bed is somewhat more siliceous than the upper bed. The ore is sharply differentiated from both the hanging wall and the foot wall. The hanging wall consists of thick-bedded dark-green fine-grained quartzite, locally containing an abundance of disseminated crystals of pyrite. Near the surface it shows brown spots of iron oxide derived from the oxidation of the pyrite. The brownish-green sandstone between the two ore beds generally consists of a single bed, but locally it is divided by bedding planes into several layers. The foot-wall rock underneath the lower ore bed is a thin-bedded bluish-green shaly sandstone, fairly hard and in places finely laminated. It also contains some pyrite but not as abundantly as the hanging wall. The foot wall is part of a great thickness of brown, green, yellow, and gray sandy shales with interbedded sandstone which occupy the slope of the mountain below the ore bed. Above the ore bed the rocks are in general more sandy and heavier bedded. The strike and dip of the sediments are the same

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as those of the ore bed, in fact the ore layer is simply one of a series of beds.

The mines are operated as open stopes and trenches, and workings have gone but slightly deeper than the level of the bottoms of cross-cutting ravines.

The mines near Blue Ridge Springs are on the southeastern slope of the ridge at about the same elevation as those near Buchanan. The ore bed is traceable here for a distance of about 3 miles and is from 4 to 12 feet in thickness. It strikes approximately N. 60° E. and has a general dip of 30° NW., a dip opposite to that of the bed at Buchanan.

Three mines have operated along this bed, the Edith mine occupying the northeastern portion, the Grubb-Specular the center, and the Lemon mine the southwestern portion. The ore at this locality is confined to one bed, the 6-inch bed present at Buchanan having disappeared. The ore is similar in character to that farther to the north, though in general it is more siliceous and therefore of a somewhat lower grade. The sand grains are larger and more abundant and are in many places interspersed with tiny quartz pebbles. Locally thin lenses of shaly material are embedded in the ore, but sharply separated from it. The associated rocks are sandstones, quartzites, and sandy shales of lower Cambrian age which have the same strike and dip as the ore bed. The hanging wall for several feet above the ore bed consists of shaly sandstone very much fractured and stained by limonite near the surface, but green and solid underground. The foot wall is more compact near the surface and consists of thicker beds. Both hanging and foot walls are brownish green near the surface but underground they are a deep bluish green and are hard and quartzitic. Pyrite crystals occur disseminated in the hanging-wall rock.

In the Edith mine the ore is taken out through a tunnel crosscutting the ore bed. Formerly the mining operations were conducted in open trenches and stopes from the surface, but the old workings have now been abandoned. The ore bed is faulted underground, and locally the dip is apparently opposite to that at the surface.

The Dewey and Ironville mines are situated near Montvale, about 3 miles east of the Edith mine. The ore bed here has the same variations in thickness as at the Edith mine and has a nearly vertical dip. The strike is approximately east-northeast.

The Griffin-Specular mine is situated on the north slope of Buck Mountain. The ore bed has a thickness of about 2 feet at this locality and strikes approximately east and west.

Character and origin of the ore.—As has been stated the ore is a very siliceous dark-red hematite, the silica being present in the

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form of sand grains and small quartz pebbles. Along cracks there is in many places a thin selvage edge composed of a dark-green mineral, probably chlorite. Besides this, there are present locally small gray or reddish clay balls. For the most part, however, the ore is hard and dense. The iron content ranges from less than 35 per cent to 45 per cent, and the silica content from 30 to 40 per cent. The following are analyses of ore from various mines.[a] (See also analysis 1, p. 222.)

Analyses of siliceous specular hematite from the Blue Ridge.[a]

	1.	2.	3.	4.	5.	6.	7.	8.
Fe	44.06	33.34	39.52	42.64	37.09	34.66	36.90	40.97
SiO_2	.....	41.14	.....	.....	36.91	39.06	34.85	31.16
P	.462	.....	.393	.409	.37	.39	.28	.....
Mn	.....	.....	.....	.....	.27	.15	.23	.....

[a] Analyses 1, 3, and 4, from Benton, E. R., op. cit., pp. 277, 278; 2, 5, 6, 7, and 8, from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, pp. 444, 445, 447, 472. All but 2 and 8 in the natural state.

1. Arcadia mine. Analysis by F. A. Gooch.
2. Arcadia mine. Analysis by R. J. Holden.
3. Arcadia mine. Analysis by F. A. Gooch.
4. Wood mine. Analysis by F. A. Gooch.
5. Edith mine. Analysis by Virginia Iron, Coal and Coke Co.
6. Ironville mine. Analysis by Virginia Iron, Coal and Coke Co.
7. Dewey mine. Analysis by Virginia Iron, Coal and Coke Co.
8. Griffin-Specular mine. Analysis by R. J. Holden.

The bedded character of the ore layer, its conformity in strike and dip with the associated rocks, its sharp contact with these rocks, and the presence of sedimentary material in the ore itself point to the conclusion that, like the Clinton fossil ores, the specular hematite ores of the Blue Ridge are the result of original deposition. There is this difference, however, that whereas the Clinton ores were deposited in association with calcareous material the specular ores were deposited with quartz sand.

CLINTON FOSSIL HEMATITE.

Distribution and geology.—The fossil hematite ores occur as beds in the Clinton (Rockwood) formation of the Silurian system. The rocks of this formation are widely distributed through the western and southwestern parts of Virginia, but only in two localities are ores present in workable quantities—in Alleghany County, in the western part of the State, and in Wise and Lee counties, in the southwestern part.

In Alleghany County fossil ore has been produced at two localities—at the Horse Mountain mine, on the southeast slope of Horse Mountain, 3 miles southwest of Low Moor, and at the Iron Gate mine, at Iron Gate, on the face of the bluff northeast of Jackson River. The Horse Mountain mine is in operation at the present

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time. Clinton ore beds are known to outcrop also along many ridges elsewhere in this vicinity and to the southwest, but for the most part they are too thin and of too low grade to be mined at the present time.

In Wise and Lee counties the ore is found along outcrops of the Clinton (Rockwood) formation, extending southwestward from Big Stone Gap for about 25 miles.[a] There are two principal localities where ore is being mined. The first of these is on Wallen Ridge and in Powell Valley, extending for 3 or 4 miles south of Big Stone Gap. It embraces four mines, the Yeary, Irondale, Keystone, and Oreton. The second locality is along Poor Valley Ridge, extending for a distance of about 15 miles southwest from Pennington Gap, which is about 10 miles southwest of Big Stone Gap. There are eight mines along this belt—the Pennington, Lavine, Ben Hur, Truro, Noes Siding, Grabill, Boones Path, and Ewing mines, most of which are on the north slope of Poor Valley Ridge.

The rocks of the Clinton (Rockwood) formation are largely sandstone and sandy shales. Fossil ores occur interbedded with the latter. In the Alleghany County region the formation has a thickness of 300 to 600 feet, the average being about 450 feet.

Eckel gives the following section, measured by E. O. Ulrich, of the Clinton (Rockwood) formation at Iron Gate:

Section of the Clinton and associated formations at Iron Gate, Va.[b]

	Feet.
Lewistown ("Helderberg") limestone, thin-bedded, shaly limestone shales	322
Rockwood ("Clinton"):	
Heavy sandstone	42
Alternating sandstone and shale	125
Sandstones and shales overlying a red mottled shale, with a heavy ferruginous sandstone (block ore) near the base	115
Shales with fossil ore bed near top	170
Clinch ("Medina") hard massive, white sandstone	50

The section on Horse Mountain is somewhat different from this, for there a heavy bed of white, quartzitic sandstone more than 30 feet thick immediately overlies the ore-bearing shales, there being only from a few inches to 2 feet of shale between it and the ore bed. Only one ore bed is present in the Alleghany County region, but locally there are in addition one or two thin beds of red ferruginous fossiliferous sandstone closely approaching the ore bed in appearance.

In the fossil-ore district of Wise and Lee counties the Clinton (Rockwood) formation consists of shales and sandstones of variable

[a] Holden, R. J., op. cit., pp. 463–467. Campbell, M. R., Geol. Atlas U. S., folio 12 (Estillville).

[b] Eckel, E. C., Oriskany and Clinton iron ores of Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 185.

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thickness and composition and has an average thickness of 400 to 600 feet. Here and there outside of the ore-bearing area, as on Clinch Mountain, the thickness decreases to less than 100 feet, but at such localities the ore beds are generally absent. Three workable ore layers occur in this area, known as No. 2, No. 3, and No. 4. Bed No. 2 is the lowest, stratigraphically. About 175 to 225 feet above it lies bed No. 3, and bed No. 4 is about 80 to 90 feet above this. The middle bed has been mined most extensively, and the lowest the least extensively. At very few localities are all three beds productive.

Ore beds.—The strata at Iron Gate have been sharply folded into a northeast-southwest anticline, overturned to the northwest, so that the east limb describes a gentle arc across the upper half of the bluff. The Clinch sandstone forms the lower or inner portion of this limb,

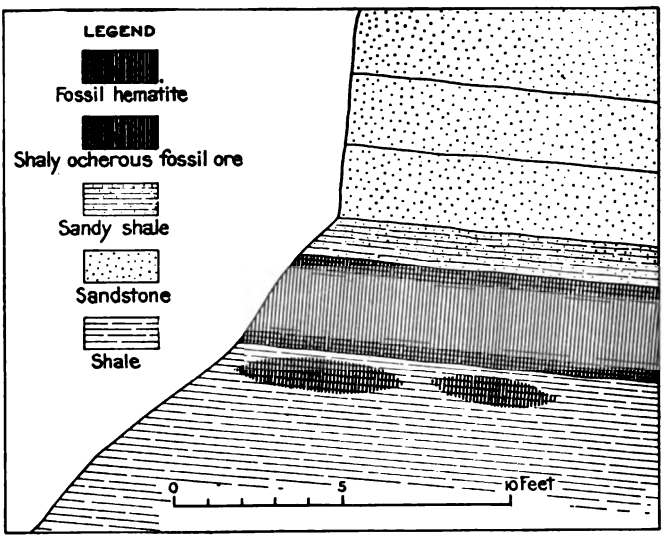

FIGURE 18.—Vertical section through the fossil hematite bed and adjacent rocks at the Horse Mountain mine, near Low Moor, Va.

and immediately above it are Clinton (Rockwood) shales containing near the top the ore bed, which is generally less than 1½ feet thick and irregular. The leached surface ore (soft ore) has all been removed and the unleached ore (hard ore) is of low grade.

At the Horse Mountain mine the ore bed is exposed along the southeast face of the ridge. The main workings are near the summit, but to the north the bed appears lower on the slope. It dips about 10° to 20° NW., into the ridge. The ore bed has an average thickness of somewhat less than 2 feet and generally consists, near the surface, of a hard red layer, with blocky fracture, which above and below grades into soft brown ocher. (See fig. 18.) The middle layer is, as a rule, over a foot in thickness. Above the ore bed is a layer of shale from a few inches to a foot and a half in thickness, succeeded by a heavy-bedded brownish-white quartzite 30 to 35 feet

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thick, which forms a very marked bluff near the crest of the ridge. The following is a detailed section taken in one of the eastern slopes.

Section of the fossil ore bed and adjacent formations on Horse Mountain, Va.

		Feet.	in.
Heavy-bedded brownish-white quartzite		30+	
Brownish-gray sandy shale		1	3
Ore bed	Soft yellow and dark-brown ocher		5
	Solid blocky red hematite	1	3
	Compact yellow and brown ocher		9
Gray shale with ocher lenses several feet thick near the top. Some of the lenses are connected into a layer 5 or 6 inches thick		10+	

The following sections, taken by Eckel[a] show slight variations from the above.

Sections of the fossil ore bed and adjacent formations on Horse Mountain, Va.

1.

	Ft.	In.
White quartzite	35	
Shale		2
Sandstone		3
Shale		½
Sandstone		3
Shales and thin sandstone		10
Fossil ore, brown and porous		7
Fossil ore, red and fairly hard	1	2
Ochery clay		6
Shales	2	

2.

White quartzite	30	
Shales		2
Red fossil ore	1	4
Ochery shales and thin sandstones	1	
Shales and sandstones	2	

In a few places a 3-foot bed of red ferruginous sandstone with fossils like those in the ore bed is exposed about 15 feet stratigraphically below it. This sandstone is interbedded with gray shales.

The Clinton (Rockwood) strata immediately south of Big Stone Gap are on the southeast limb of a northeast-southwest anticline. The beds containing the ores therefore dip to the southeast. Wallen Ridge is formed by the Clinch sandstone, which stratigraphically is immediately below the Clinton (Rockwood). On the slope of this ridge and in the valley to the southeast the Clinton (Rockwood) formation carries ore beds Nos. 3 and 4. The formation extends southwestward along the southeast slope of Wallen Ridge for nearly 20 miles into Lee County, but ore of workable thickness has been found at only a few localities along this belt.

[a] Eckel, E. C., op. cit., p. 188.

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The ore beds on Poor Valley Ridge are on the opposite side of the anticline from those just mentioned and for the most part dip steeply to the northwest. Three ore beds (Nos. 2, 3, and 4) are present, associated with sandstones and sandy shales. The strata extend southwestward into Tennessee, where they connect with the beds of the La Follette district.

Character and origin of the ores.—The Clinton ore of Virginia is largely of the variety called fossil ore, though some oolitic ore is found. The fossil ore varies in texture from very coarse to fine, according to the nature of the fossil fragments composing it; these consist largely of pieces of brachiopods, crinoid stems, and mollusks. The ore mined in Alleghany County is all of the soft variety from which the calcium carbonate has been removed by leaching of surface waters. It varies in color from yellowish brown to reddish black, but generally is of a dark-red color. The following table gives analyses of ore from Alleghany County. (See also analysis 2, p. 222.)

Analyses of Clinton ore from Alleghany County, Va.[a]

	1.	2.	3.	4.
Fe	57.00	44.82	41.71	46.5 –46.0
Mn	.15			
P	.678		.444	.49– .48
SiO_2	7.12	15.51		
Insoluble				19.90–20.24
CaO	1.46			

[a] Analyses 1 and 4 from Eckel, E. C., Oriskany and Clinton iron ores of Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 188. Analysis 2 from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, p. 442. Analysis 3 (natural state) from Benton, E. R., Iron-ore mines of Virginia: Tenth Census, vol. 15, Mining industries, 1886, p. 281.

1, 2. Horse Mountain mine. Analyses by Low Moor Iron Co.
3. Horse Mountain mine. Analysis by F. A. Gooch.
4. Iron Gate mine. Analysis by Longdale Iron Co.

The ore of southwestern Virginia is of a lower grade and more siliceous than the Horse Mountain ore, as shown by the following analyses:

Analyses of Clinton ore from Lee and Wise counties, Va.[a]

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Fe	44.90	40.14	42.34	50.50	43.20	34.01	36.00	42.30	40.91	34.09
SiO_2	15.81	27.98	18.36	18.75	22.31	34.50	33.37	27.60	16.70	6.58
P	.29	.32	.29	.18	.34	.27	.23	.19	.45	.58
CaO	.22	.61	.11		.56			.10	5.18	7.72
MgO									.93	3.95
Mn						.16	.16			

[a] Holden, R. J., op. cit., pp. 464–467.

1. Oreton mine. Analysis by Union Iron and Steel Co.
2. Irondale mines. Analysis by Union Iron and Steel Co.
3. Yeary mine. Analysis by Union Iron and Steel Co.
4. Pennington mine. Analysis by A. S. McCreath.
5. Lavine mine. Analysis by Union Iron and Steel Co.
6. Ben Hur mine. Analysis by Virginia Iron, Coal and Coke Co.
7. Truro mine. Analysis by Virginia Iron, Coal and Coke Co.
8. Noes Siding mine. Analysis by Union Iron and Steel Co.
9. Boones Path mine. Analysis by Union Iron and Steel Co.
10. Ewing mine. Analysis by Union Iron and Steel Co.

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The foregoing analyses show that most of the ore mined is of the "soft" variety, nearly all of the lime having been leached out. Nos. 9 and 10 still contain some lime and approach hard ore in composition.

The origin of the Clinton ores has been a matter of much controversy, but it is now almost universally agreed that they are original sedimentary deposits. This subject is adequately discussed by Burchard[a] with regard to the ores of the Birmingham district in Alabama.

MOUNTAIN BROWN ORES.

Distribution and geology.—Mountain brown ores are found in Virginia in two narrow belts. One extends along the west slope of the Blue Ridge from Front Royal, Warren County, on the north, to a point about 10 miles south of Roanoke, Roanoke County, on the south. The other belt is an extension of this one in the New River district, in southwestern Virginia. It extends from a point about 5 miles east of Allisonia west-southwestward to a point south of Marion. Between the two belts there is a barren area about 40 miles in length. At few places is either belt more than a few miles wide.

The ores are associated with the lower Cambrian quartzite and with residual material overlying it. They occur in small irregular deposits of a variety of types and are scattered at intervals along the belts mentioned. There is a marked grouping of deposits locally along the Blue Ridge belt, illustrated by the groups of mines at Shenandoah, Grottoes, Vesuvius, and Buena Vista and south of Roanoke.

In northwestern and west-central Virginia the Blue Ridge lies on the boundary between the crystalline and metamorphic rocks of the Piedmont region and the Paleozoic sediments of the Appalachian Valley belt. South of Roanoke, however, the line of contact and the Blue Ridge separate, the contact running along a series of low ridges until it reaches the Iron Mountains, which it follows southward into Tennessee, and the Blue Ridge, running farther to the southeast, across the crystalline area. (See fig. 15.) The ore belts follow the line of contact very closely.

By far the larger number of ore deposits occur in residual material above the lower Cambrian quartzite in the Blue Ridge region and above the Erwin quartzite in the New River district. A few occur in the solid quartzite, but very rarely are any ores found in the series of shales and quartzites between this formation and the crystalline rocks.

Along the Blue Ridge area the quartzite as a rule forms the western slope of the mountains, and clay, sand, and fragmental material, partly residual and partly fluviatile, form a gently sloping bench at

[a] Burchard, E. F., The Clinton iron-ore deposits in Alabama: Trans. Am. Inst. Min. Eng., vol. 39, 1908, pp. 997–1055.

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the base. On this bench, near the base of the ridge, are located most of the iron-ore deposits. The Sherwood limestone and "Buena Vista" shale do not outcrop very abundantly along the Blue Ridge. In many places they are doubtless hidden under the residual material forming the bench just mentioned, and elsewhere they are cut out by faulting. In the valley to the west are the Natural Bridge and overlying limestones of the Shenandoah group.

In the New River district the distribution of the rocks is also complicated on account of folding and faulting. The valleys of New River and Cripple Creek are in the Shady limestone;[a] the ridges north and south of them consist of the Erwin quartzite, except Draper Mountain, at the northeast end, which is made up of Devonian and Silurian sediments. Locally, within the New River valley, there are minor ridges of the Erwin quartzite, such as Roaring Falls Mountain. The distribution of the mountain ore deposits is in general coextensive with the areas of the Erwin quartzite. The ores occur mainly along the north slope of the quartzite ridge south of New River and Cripple Creek, but also on both sides of the quartzite ridges within the valley, and in a few places, as south of Marion, on the south slope of the ridges north of the valley.

Tertiary or Pleistocene sediments are associated with the ore in many of the deposits. In some places they consist of variegated, much decomposed, angular conglomeratic material; elsewhere of a mixture of bright-colored clays; and in still other places of a mixture of sand, pebbles, and bowlders, largely of quartz and to some extent roughly stratified. At one locality near Buena Vista variegated clays containing lignite and rounded pebbles and bowlders are associated with soft, finely laminated gray shales, containing an abundance of fossil leaves, of both conifers and hard-wood trees. It is very difficult to distinguish the Tertiary or Pleistocene clays from the residual clays, except where the former contain pebbles and carbonaceous material. Therefore it is impossible to say with which clay most of the mountain ores are associated.

Ore deposits.—The mountain ore deposits are distinguished from the valley ore deposits by their structure, by the grade of the ore, and by the material with which they are associated. The valley ores are of higher grade than the mountain ores and are invariably disseminated through dark-red and ocherous-yellow, porous, crumbly clay lying on the uneven surface of the Shady or other limestones. The mountain ores, on the other hand, are associated with sandy, pebbly, or compact variegated clays, in which they occur as large bodies or as pockets of angular fragments. They are always found at or near the contact of the lower Cambrian or Erwin quartzite with

[a] Keith, Arthur, personal communication.

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overlying formations, in residual material which appears to be largely derived from the quartzites. In some places the contact is normal; elsewhere it is marked by a fault. In the Blue Ridge district faulting is extensive, and the lower Cambrian quartzite may be in contact with the Sherwood limestone, "Buena Vista" shale, or Natural Bridge limestone. In the New River district the faulting is pronounced, but not as extensive as along the Blue Ridge, so that the Erwin quartzite always remains in contact with the Shady limestone. Many deposits are found in brecciated zones along the fault plane, either in the bed rock or in residual material above it. Other deposits, however, occur along this contact where faulting is not evident and appear to be simply concentrations on the upper surface of the quartzite.

The mountain brown-ore deposits are of many different types, chief among which may be mentioned the following:

1. Pocket deposits in clay, either residual or fluviatile.
   (*a*) Irregular replacement masses of large size.
   (*b*) Mammillary masses associated with bright-colored clay.
   (*c*) Angular fragments of various sizes, replacements along seams, etc., scattered through brown and variegated clay.
2. Deposits in shale. Small replacements along seams and fractures.
3. Deposits in quartzite.
   (*a*) Breccia deposits accompanied by replacement.
   (*b*) Vein deposits along faults.

1. The deposits in clay range in size from single pockets hardly more than a few hundred feet in diameter to large deposits consisting of a group of pockets or masses several hundred yards in extent. Such groups are in many places connected into a series extending along the strike of the rocks for 5 miles or more, causing the grouping of mines already mentioned. The greatest depth to which the deposits have been operated is about 200 feet, but most of the deposits are probably shallower than this, though it is not at all certain that some may not be deeper. The pocket deposits in clay are by far the most abundant of the mountain ores.

As each deposit is generally made up of a group of pockets, so each pocket is made up of several ore masses or of many fragments embedded in clay. Several different types of ore generally are associated in a deposit.

(*a*) The most important deposits, though the fewest in number, are composed of large, irregular ore masses from 20 to 150 or 200 feet in diameter. They are apparently replacements of limestone, as is indicated by the following facts: Limestone has been found in association with the deposits, and in a few places, as at the Grubb mines, has been known to occur in the unaltered interior of large fragments of iron ore. In a great many places chert, a characteristic associate

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of limestone, is found with the iron ore. These large masses are not solid ore, but are much broken up and fractured so that they consist of many angular fragments of varying size, intermixed with considerable clay and sand. They generally have a longer axis running in the direction of the strike of the rocks. Such deposits occur at the Happy Creek mine, near Front Royal, Warren County; at the Buena Vista mine, near Buena Vista, Rockbridge County; and at the Grubb mine, near Blue Ridge Springs, Botetourt County.

(*b*) The mammillary masses are perhaps the most characteristic forms in which the mountain ores occur. (See fig. 19.) These masses vary in length from about 10 to 100 feet and have a width equal to about one-third of their length. Many of them are irregular in outline, but all have one feature in common, namely, a rounded,

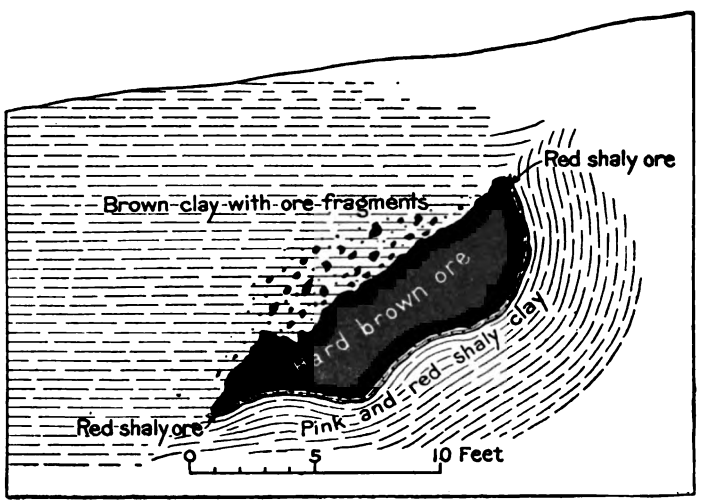

FIGURE 19.—Vertical section showing the structure of mountain brown ore occurring as a mammillary mass in clay at the Mary Creek mine, near Vesuvius, Va.

bulging surface. As a rule, the ore composing such masses contains many impurities, chief among which are sand and clay. Much of the ore is highly manganiferous, the manganese being present as psilomelane or pyrolusite and generally occurring in cavities associated with needle limonite. The ore in the interior of the masses is generally of a brown color and is in many places of a fairly good grade (see analysis 3, p. 222); the ore which occurs on the outside is red in color from half an inch to several inches from the surface, contains a great deal of sand and clay, and is of low grade. In some places the entire mass consists of red low-grade ore. (See analysis 6, p. 222.)

Generally the ore which composes these masses is hard and solid and not much broken up or fractured. The masses appear to have no regularity of position in relation to the underlying rocks. Their form and structure suggests the deposition of iron in clay by meteoric

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waters along trunk channels of circulation. Replacement and alteration progressed as more material was added, and the interior ore became of higher grade than the surface ore. The clays associated with the deposit are locally bright red, especially near the contact with the mammillary surfaces. The best examples of the deposits of this class are found at the Bare Bank and Mine Bank mines, in Augusta County, near Vesuvius; at the Mary Creek mine, in Rockbridge County, near Vesuvius; and at the Buena Vista mine, near Buena Vista, Rockbridge County.

(*c*) The third class of pocket deposits in clay consists of angular fragments of various forms and sizes scattered through variegated or brown clays. The fragments were probably at one time parts of larger masses, which have been broken up by the slumping of the clay. These masses were mostly small veins and replacements along lines of fracture or bedding planes, as is shown by the fact that many of the fragments are still arranged along such planes. Here and there fragments are grouped in little pockets, and in such places they were probably originally parts of small disconnected masses. The fragments vary from a fraction of an inch to more than a foot in diameter, though for the most part they are small. They are in numerous places associated with angular rock fragments, such as chert and quartzite.

The fragmental deposits consist mostly of hard brown ore, but locally contain pockets and stringers of soft sandy ore.

This class of mountain ore is very abundant, the following being among the typical occurrences: The Fox Mountain mine, near Elkton, Rockingham County; the Mount Vernon group of mines, near Grottoes, Rockingham County; the Crozier mine, near Greenville, Augusta County; the Buena Vista mines, near Buena Vista, Rockbridge County; the Troutville mine, near Troutville, Botetourt County; the Farris mine, near Allisonia, Pulaski County; the Foster Falls, Tipton, and Crawford mines, near Foster Falls, Wythe County; the Poplar Camp, Gregory, and Bailey Crockett mines, near Ivanhoe, Wythe County; and the Currin Valley mine, near Attoway, Smyth County.

2. In a few localities brown iron ores occur as a direct replacement of shale, layers of which are abundant locally in formations overlying the quartzite along the Blue Ridge. They are of no commercial value, the deposits being small and the ore of low grade. The replacement takes place along certain layers, so that the deposits generally consist of alternating layers of shale and ore. The layers are generally not more than 1 or 2 inches in thickness and are discontinuous, so that in reality they are flat lenses, the ends of which dovetail with other lenses. It is probable that the layers that have suffered the most alteration are those which originally contained the greatest amount

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of calcareous material. Deposits of this type occur at the Lock property, near Front Royal, Warren County; at the Garrison mine, near Shenandoah, Page County; and at the Black Rock mine, in Augusta County, near Vesuvius.

3. The deposits in the quartzite are not very abundant, and only a few of them have been mined.

(*a*) The breccia and replacement deposits are usually of very low grade on account of the excessive amount of sand and quartzite fragments which they contain. In some of them the principal deposition has taken place along a brecciated zone, and replacement has occurred in the surrounding rocks, with this zone as a center. A mass of rock, perhaps several hundred feet in extent, suffers replacement and staining; but while some layers may be thoroughly replaced, others are merely stained with limonite. In some deposits of this type there is no brecciated center, but the entire deposit consists of a single pocket of replaced quartzite altered to different degrees, or of several distinct masses of such material grouped together. Typical deposits in quartzite occur at the Rileyville mine, near Rileyville, Page County; at the Midvale mine, near Midvale, Rockbridge County; and at the Morris mine, near Foster Falls, Wythe County.

(*b*) The fault and vein deposits in quartzite form a distinct type, very easily recognized and distinguished from all that have so far been described. Only two such deposits of sufficient importance to be mined have been found—the Big Ike mine, in Warren County, near Overall, and the Dixie mine, near Vesuvius, Rockbridge County. Similar deposits of small extent are found near Vesuvius and near Buena Vista, Rockbridge County. The deposits may occur along either dip or strike faults, but the largest deposit, that at the Dixie mine, is in a dip fault. This deposit (see fig. 20) strikes a little east of north and dips about 65° W., while the adjoining rocks strike N. 70° E. and dip about 60° N. It has been worked for a distance of several hundred yards and to a depth of about 250 feet and has been found to vary in thickness from 2 to 20 feet. Its center generally consists of pure glossy black limonite, and along the sides there are many partly replaced angular quartzite fragments. The quartzite next to it contains numerous small veins of limonite along the contact. The ore is very high in phosphorus, some of it containing several per cent. (See analysis 4, p. 222.) This has been traced to the mineral dufrenite, a green hydrated iron phosphate, which is locally present in such amounts as to give a green tint to the ore. The other deposits of this type are similar to the Dixie deposit, though of much smaller extent.

Character and origin of the ore.—As regards texture, the mountain ores are of three very distinct types—(1) black, glossy amorphous ore, (2) needle ore, and (3) brown, earthy amorphous ore. The first

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occurs as a cavity filling, especially along fault planes or in small veins and in breccia zones in quartzite. It is usually very hard and breaks with a conchoidal fracture. The needle ore also occurs as a cavity filling, but is more usually associated with the pocket deposits in clay, where it lines small cavities in the ore masses. It consists of fine, parallel needles grouped at right angles to the wall of the cavity. The color is usually dark brown. The third type is by far the most common form of mountain ore, as nearly all the deposits in clay and shale and part of those in the quartzite have this texture. It is the

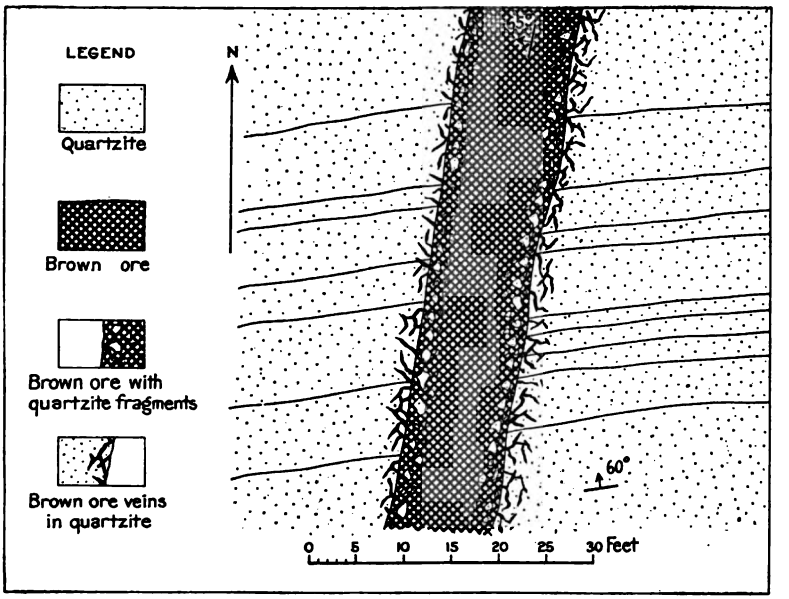

FIGURE 20.—Horizontal plan showing the structure of the brown-ore vein occurring along a fault in quartzite at the Dixie mine, near Vesuvius, Va.

form which limonite assumes when it replaces other materials, such as limestone, clay, or shale. There is a slight variation in texture, according to the material replaced. The ore is most pure and has a dark-brown color where it replaces limestone; but as the impurities increase it becomes lighter, so that ore which replaces shale and clay is generally of a rather light-brown color. The needle ore is the highest grade of brown ore. The glossy black ore, though rich in iron, generally contains considerable phosphorus, which makes it of low grade. The brown replacement ore, as a rule, contains a good many impurities, mainly in the form of sand and clay. (See analyses 3, 4, and 5, p. 222.)

The mountain brown ores are impure hydrated oxides, varying in composition between göthite and limonite and yielding on the average between 35 and 50 per cent of metallic iron. The impurities chief in

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quantity are silica and alumina, derived from included sand and clay. The silica content varies from 10 to 30 per cent. Phosphorus is the most injurious of the impurities present and varies in quantity from 0.10 to 2 per cent, thus making all the ore of non-Bessemer quality. The manganese content varies from 0.1 per cent upward. Where 1 or 2 per cent of manganese is present the ore produces a high-manganese pig iron which is used for special purposes. Ore containing a considerable percentage of manganese (about 10 per cent and upward) is used in the manufacture of spiegeleisen.

The following are analyses of mountain ores (see also analyses 3, 4, 5, and 6, p. 222):

Analyses of Virginia mountain brown ores.[a]

	1.[b]	2.[c]	3.[c]	4.[b]	5.[b]	6.[b]	7.[b]	8.[b]	9.
Fe	49.48	41.35	37.08	41.17	41.15	45.41	45.34	52.50	38.95
SiO_2	.....	21.95	25.37	20.03	.....	.....	.....	.....	.....
Insoluble	.....	.....	.....	.....	.....	.....	.....	.....	28.29
P	.59	.33	1.82	.215	.231	.274	.206	.229	.10
Mn	.75	.60	.....	.....	.....	.....	.....	.....	.....

	10.	11.	12.[b]	13.[b]	14.	15.[c]	16.[b]	17.[b]	18.
Fe	41.13	48.50	41.20	38.68	47.80	39.59	40.38	40.67	35.61
SiO_2	.....	.....	14.08	20.91	13.40	.....	20.11	18.09	28.50
Insoluble	14.83	14.46	.....	.....	.....	.....	.....	.....	.....
P	.26	.....	1.23	1.14	.14	.39	.55	.53	.069
Mn	8.22	.....	1.13	1.20	.44	.48	.47	1.24	.30

	19.[c]	20.[b]	21.	22.	23.	24.[b]	25.	26.
Fe	43.60	35.96	40.77	47.91	49.89	35.63	42.65	40.00
SiO_2	.....	17.10	13.92	9.69	11.40	20.21	.....	15.00–20.00
P	.74	.25	1.19	1.98	1.22	.72	.12	.25– .35
Mn	1.56	4.52	6.80	1.23	.85	.60	.....	2.00– 5.00

[a] Analyses 1, 2, 3, and 9 to 26 from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, pp. 430–461.
Analyses 4 to 8 from Benton, E. R., Iron-ore mines of Virginia: Tenth Census, vol 15, Mining industries, 1886, pp. 286–287.
[b] Natural state.
[c] Dried at 212° F.

1. Happy Creek mine, near Front Royal, Warren County. Analysis from H. J. Siebel, jr.
2. Boyer mine, near Shenandoah, Page County. Analysis by Alleghany Ore and Iron Co.
3. Rileyville mine, Rileyville, Page County. Analysis by Alleghany Ore and Iron Co.
4. Fox Mountain mine, near Elkton, Rockingham County. Analysis by F. A. Gooch.
5. Raines mine, near Grottoes, Rockingham County. Analysis by F. A. Gooch.
6. Miller mine, near Grottoes, Rockingham County. Analysis by F. A. Gooch.
7. Mount Torrey mine, near Lyndhurst, Augusta County. Analysis by F. A. Gooch.
8. Kennedy mine, near Stuart's Draft, Augusta County. Analysis by F. A. Gooch.
9. Black Rock mine, Augusta County, near Vesuvius. Sampled by A. S. McCreath.
10. Mine Bank mine, Augusta County, near Vesuvius. Sampled by A. S. McCreath.
11. Dixie mine, near Vesuvius, Rockbridge County. Analysis by Alleghany Ore and Iron Co.
12. Grubb mine, near Blue Ridge Springs, Botetourt County. Analysis by Virginia Iron, Coal and Coke Co.
13. Rorer mine, near Roanoke, Roanoke County. Analysis by Virginia Iron, Coal and Coke Co.
14. Tasker mine, near Hiwassee, Pulaski County. Analysis by West End Furnace Co.
15. Farris mine, near Allisonia, Pulaski County. Analysis by Pulaski Iron Co.
16. Morris mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
17. Hurst mine, near Reed Island, Wythe County. Analysis by Virginia Iron, Coal and Coke Co. (Semilimonite.)
18. Crawford mine, near Patterson, Wythe County. Analysis by Virginia Iron, Coal and Coke Co. (Semilimonite.)

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19. Tipton mine, near Tipton, Wythe County. Analysis by Pulaski Iron Co.
20. Foster Falls mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
21. Poplar Camp mine, Poplar Camp, Wythe County. Analysis by R. J. Holden.
22. Indian Camp mine, near Poplar Camp, Wythe County. Analysis by New River Mineral Co.
23. William Jackson mine, near Ivanhoe, Wythe County. Analysis by New River Mineral Co.
24. Gregory mine, near Ivanhoe, Wythe County. Analysis by New River Mineral Co.
25. Norma mine, near Cripple Creek, Wythe County. Analysis by Pulaski Iron Co.
26. Currin Valley mine, near Attoway, Smyth County. Analysis from Dr. J. S. Apperson.

The mountain brown iron-ore deposits are clearly concentrations by meteoric waters. The iron was derived largely from the overlying limestone and shale formations, though perhaps partly from the underlying quartzite. The materials composing these formations were transported from the Piedmont region, where they were originally in the form of crystalline and metamorphic rocks. The shale formations contain a large quantity of undecomposed ferrous silicate minerals and in many places also considerable pyrite; the limestone formations contain pyrite and probably also iron carbonate; and the quartzite locally contains an abundance of pyrite. On weathering the iron in these formations is carried downward and precipitated as ferric oxide where conditions are favorable. Such favorable conditions are afforded by fault planes and an impervious basement of quartzite, and it is here that the deposits occur. The iron is carried downward through the shale and limestone residuum by successive precipitations until it reaches the underlying relatively impervious quartzite and is there concentrated. It replaces limestone and clay beds, forming pocket deposits in residual clay, and where possible penetrates fractures in the quartzite below, forming breccia and fault deposits. The presence of deposits in both residual and Tertiary or Pleistocene clays points toward a continuous concentration. Apparently this process is going on at the present time, for chalybeate springs are found in the neighborhood of many iron-ore deposits. The location of the deposits depends partly on the structure of the rocks and partly on the location of the original iron minerals in the overlying formations.

The ores in the limestone residuum which have not reached the underlying quartzite are generally in a porous and disseminated condition and constitute the valley or limestone ores described later.

VALLEY BROWN ORES.

Distribution and geology.—The valley ores (also called limestone limonites) extend along the same general area as the mountain ores, being distributed through a belt adjoining the mountain ores on the west and northwest. The belts generally overlap on the borders, especially in the New River region.

In the Blue Ridge belt valley ores are not very abundant, being scattered at intervals through the limestone area in the valley west

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of the Blue Ridge from the Maryland boundary on the north to Roanoke on the south. Only about six or eight deposits have been worked. In the New River district, however, the valley ore deposits are as numerous and important as the mountain ore deposits, if not more so. In this district the valley ore deposits are distributed through the valleys of New River and Cripple Creek between the quartzite ridges on the north and south. The maximum width of the valleys is about 6 or 7 miles, but the ores are confined to a somewhat narrower limit. The length of the combined valleys is about 55 miles. As has been mentioned, quartzite ridges carrying mountain ores occur in these valleys locally, though for the most part the mountain ores are confined to the southern border.

The valley ores occur as porous masses and disseminated particles in residual material derived from the Shady limestone in the New River district and from the Natural Bridge limestone in the Blue Ridge belt. It is possible that a few valley ore deposits along the Blue Ridge may be associated with the Sherwood limestone, but such a connection has not been established. The Sherwood is absent for considerable stretches on account of faulting, and where it is present its structure is generally unfavorable for ore concentration on account of the steep dips.

In the New River region the Shady limestone is nearly horizontal and only the lower portion of it is present, the upper part having been eroded. The bed rock is but a short distance below the surface and outcrops are abundant.

Ore deposits.—The valley ore deposits are not of the variable nature that characterizes the mountain ore deposits, but preserve great constancy with regard to both the form of the deposits and the character of the ores.

The valley ore deposits in the Blue Ridge are small and generally unimportant. They occur in clay on the surface of the Natural Bridge limestone or in crevices extending down into it. At the Buck Hill mine, near Midvale, Rockbridge County, there is a crevice 30 to 40 feet deep and 20 to 30 feet wide. The ore occurs in clay, in fragments or porous masses mixed with considerable ocher. In most of the valley ore mines along the Blue Ridge the ores are disseminated through dark-red clay on the surface of the limestone and do not extend to a great depth.

The valley ore deposits in the New River district, though associated with a different limestone formation, are similar in structure to those along the Blue Ridge. They are much greater in horizontal than in vertical extent, few deposits being more than 50 feet deep, though they may cover an area of 15 to 20 acres. The bottom of the deposits rests on the uneven surface of the limestone. (See fig. 21.)

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Numerous horses of limestone extend up into the overlying clay, some of them even rising above the surface of the ground. Between these horses there are abrupt depressions filled with clay through which the iron ores are disseminated. In many places there is a difference of elevation of 20 feet or more between the top of the horses and the bottom of the depressions. After the removal of the ore and clay the limestone knobs and horses present an appearance very similar to that of forms produced by wind erosion in the western United States.

The residual clays have a prevailing dark-red color and are of porous and crumbly rather than plastic character. On approaching the contact with the underlying limestone the color changes to an ocherous brownish yellow. Locally dark-brown and even black clays occur, but light-colored variegated clays are conspicuously absent.

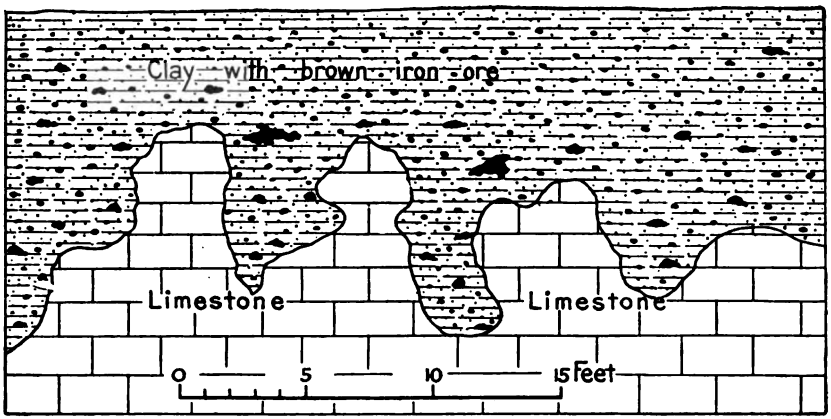

FIGURE 21.—Vertical section showing the structure of the valley brown ore deposits at the Rich Hill mine, near Reed Island, Va.

The ore is in the form of disseminated particles or large porous masses. The former vary from the size of a pea to fragments several inches in diameter; many of the latter are several feet in extent. Some of the masses and fragments are in the form and place that they were originally deposited, but elsewhere the original masses are broken into fragments and displaced by slumping of the clay beds. The ores are invariably more or less porous, and in many deposits ocher is associated with them, especially where they occur in large masses.

The large porous masses are more abundant in the ocherous clays near the limestone horses; the disseminated or gravel ore is more abundant in the dark-red clay. Much of the dark clay also contains numerous rounded pebbles of quartz and limonite in layers within a few feet from the surface.

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In the valley ore deposits the ores are not gathered into local pockets as they are in the mountain ore deposits, but are scattered throughout the clay in varying abundance. The proportion of clay to ore varies from 5 to 1 to 25 to 1 in the workable deposits, but ore is present less abundantly throughout the area of limestone residuum.

The typical valley brown ore mines in the Blue Ridge region are the Hieston mine, near Luray, Page County; the Lofton mine, near Lofton, Augusta County; and the Buckhill mine, near Midvale, Rockbridge County. Those of the New River region are the Rich Hill, Reed Island, and Underock mines, near Reed Island, Pulaski County; the Barren Springs, Bertha, Walton, Carter, Sanders, Cedar Run, Hematite, Posey, and Foster Falls mines, near Foster Falls, Wythe County; and the Sisk & Gray, Simmerman, and Ivanhoe mines, near Ivanhoe, Wythe County.

Character and origin of the ores.—The valley ores are in general richer than the mountain ores and contain fewer impurities. They are porous and to some extent honeycombed, and locally considerable quantities of ocher are mixed with them. The cavities are generally filled with clay. Needle ore is rare in these deposits, the ore for the most part being in the amorphous form and yellow or brown in color. The valley ores, like the mountain ores, consist of a mixture of various hydrated oxides. They range in iron content from 40 to 55 per cent and in silica content from 5 to 20 per cent. Phosphorus is present in sufficient quantities to make a non-Bessemer ore, but it is by no means as high as in the mountain ore, ranging from 0.1 to 0.2 per cent. Manganese is generally below 1 per cent. Sand grains and quartz pebbles are not as abundant as in the mountain ores, but the sand is common where the original limestone was sandy. Locally chert occurs in small masses and bands.

The following table gives analyses of valley brown ores (see also analysis 7, p. 222):

Analyses of Virginia valley brown ores.[a]

	1.[b]	2.	3.	4.	5.	6.	7.	8.	9.	10.
Fe	52.50	43.81	56.22	42.42	56.29	44.27	44.98	55.04	46.08	41.17
SiO_2	5.59	14.65	.....	18.92	.....	12.50	.....	.....	10.90	19.81
P	.15	.18	.034	.17	.083	.14	.....	.113	.15	.22
Mn	.46	.66	.....	.37	.....	.47	.53	.....	1.09	.97

	11.	12.	13.[b]	14.	15.	16.	17.	18.	19.	20.
Fe	41.90	58.58	49.86	42.90	45.04	43.92	42.00–44.00	44.36	42.75	44.13
SiO_2	13.80	.....	.....	19.17	19.36	16.83	14.00–18.00	14.79	13.77	20.91
P	.13	.051	.....	.09	.11	.14	.15	.11	.25	.17
Mn	1.03	.....	.30	.67	.36	.73	.40– 1.00	.39	.32	.....

[a] Analyses 1, 2, 4, 6, 7, 9 to 11, and 13 to 20 from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, pp. 448–463. Analyses 3, 5, 8, and 12 from Benton, E. R., Iron-ore mines of Virginia: Tenth Census, vol. 15, Mining industries, 1886, pp. 274–276.

[b] Dried at 212° F. All others in natural state.

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1. Clark's bank, near Allisonia, Pulaski County. Analysis by New River Mineral Co.
2. Rich Hill mine, near Reed Island, Pulaski County. Analysis by Virginia Iron, Coal and Coke Co.
3. Rich Hill mine, near Reed Island, Pulaski County. Analysis by F. A. Gooch.
4. Reed Island mine, near Reed Island, Pulaski County. Analysis by Virginia Iron, Coal and Coke Co.
5. Reed Island mine, near Reed Island, Pulaski County. Analysis by F. A. Gooch.
6. Barren Springs mine, near Barren Springs, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
7. Bertha mine, near Barren Springs, Wythe County. Analysis by Pulaski Iron Co.
8. Carter bank, near Foster Falls, Wythe County. Analysis by F. A. Gooch.
9. Sanders mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
10. Cedar Run mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
11. Walton mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
12. Walton mine, near Foster Falls, Wythe County. Analysis by F. A. Gooch.
13. Patterson mine, near Patterson, Wythe County. Analysis by Pulaski Iron Co.
14. Hematite mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
15. Posey mine, near Foster Falls, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
16. Ivanhoe mine, near Ivanhoe, Wythe County. Analysis by New River Mineral Co.
17. Ivanhoe mine, near Ivanhoe, Wythe County. Analysis by Ivanhoe Furnace Co.
18. Sisk & Gray mine, near Ivanhoe, Wythe County. Analysis by New River Mineral Co.
19. Little Wythe mine, near Cripple Creek, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.
20. Hall mine, near Castlewood, Russell County. Analysis by Union Iron and Steel Co.

The analyses of the ore from the Rich Hill (2 and 3), Reed Island (4 and 5), and Walton (11 and 12) mines show the difference in composition of the ores mined about thirty years ago and those mined at present, the latter being of much lower grade.

The valley brown ores are derived from the limestones in which they occur and from overlying formations, the iron being carried downward in successive stages and becoming more concentrated as it approaches the base of the limestone. They are not very distinctly localized, but such localization as does exist is probably due to the greater abundance of iron minerals in different areas of the overlying formations, such as local pyrite deposits, rather than to the structure of the underlying beds. The solution of the iron oxides and consequent downward movement is probably largely accomplished through the agency of organic acids, as suggested by Holden.[a] The porous and disseminated nature of the ores is due to the porous condition of the limestone clays. The valley deposits are simply deposits which have not yet reached the basement quartzite and become concentrated into large bodies, like the mountain ores. The original source of the materials is the same for both classes, so that the statement of the origin given under mountain ores applies here as well.

ORISKANY BROWN ORES.

Distribution and geology.—The Oriskany brown ores are so called on account of their association with the "Monterey" (Oriskany) sandstone. They are replacements in the upper portion of the Lewistown limestone and extend underground for variable distances from the outcrop. They are directly overlain by the "Monterey" (Oris-

[a] Holden, R. J., The brown ores of the New River-Cripple Creek district, Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 192.

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kany) sandstone or by the Romney shale where the sandstone is absent.

Deposits of this type occur locally in the western portion of the Appalachian belt, from Maryland to southwestern Virginia. The principal district is that of Alleghany County and vicinity, nearly all of the Oriskany ore produced being mined there. Minor deposits occur on Draper Mountain, in Pulaski and Wythe counties, south of Pulaski and Max Meadows; on Peters Mountain, Giles County; in the Buffalo Gap area, Augusta County; on Massanutten Mountain, Shenandoah County; and on North Mountain, in Shenandoah and Frederick counties.

In all these districts the ore occurs along the outcrop of the upper part of the Lewistown limestone wherever favorable conditions for concentration prevailed. The following is the upper portion of the Iron Gate section measured by Ulrich, part of which was given on page 229:

Section of the "Monterey" and Lewistown formations at Iron Gate.[a]

	Feet.
Romney black shale.	
"Monterey" (Oriskany):	
Sandstone and siliceous limestone	209
Calcareous sandstone	50
Siliceous limestone with many beds of chert	54
Bluish-gray limestone, with sandy beds in upper part	65
Quartzitic sandstone with two shaly beds	40
Lewistown (Helderberg) thin-bedded shaly limestone shales	322

One of the favorable conditions for the formation of the Oriskany ore deposits is a thin layer of "Monterey" (Oriskany) sandstone. Where ore deposits are present the sandstone is rarely more than 20 or 30 feet in thickness and is usually much less than that. In many places it is absent altogether, and there the Devonian shale overlies the ore.

In the Alleghany County region the Ordovician, Silurian, and Devonian rocks have been thrown into a series of parallel folds trending northeast and southwest. The folds are unsymmetrical,[b] the beds on the southeast side having low dips (5°–25° SE.), while those on the northwest side have steep dips (from 60° NW. to vertical), and in places are even overturned. After the folding erosion removed the softer rocks, as the Devonian shales, "Monterey" (Oriskany) sandstone, and Lewistown limestone, from the tops of the anticlines, exposing the hard Clinton (Rockwood) and Clinch sandstones which now form the summits of the ridges. The "Monterey" (Oriskany) sandstone and Lewistown limestone are now found on the middle slopes of the ridges and the Devonian shales lie on the lower slopes and in the

[a] Eckel, E. C., Oriskany and Clinton iron ores of Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 185.

[b] Eckel, E. C., op. cit., p. 185.

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intervening valleys. The ore deposits, therefore, occur along the slopes of the ridges and dip at varying angles toward the valleys. For the most part the workable deposits are confined to the southeast slopes, where the dips are fairly low, for reasons which will be given later.

In the other districts containing Oriskany ores, although the general structure of the rocks differs from that of the Alleghany County rocks, yet wherever ore deposits occur they occupy the slopes of mountains and the rocks containing them dip at medium low angles away from the ridges.

Ore deposits.—The ore deposits are formed as replacements in the Lewistown limestone, in the upper portion, which consists of pure, heavy-bedded limestone. Above them is the "Monterey" (Oriskany) sandstone or Romney shale, and below them the cherty middle portion of the Lewistown limestone. (See fig. 22.) The following is a typical section of the "Monterey" and Lewistown formations at the principal ore deposits in the Alleghany County district:

Typical section of the ore-bearing and associated formations in Alleghany County and vicinity.

	Feet.
Romney shale:	
Black shale	600+
Grayish blue clay	1–5
"Monterey" (Oriskany) sandstone, dark colored and iron stained	0–20
Lewistown limestone:	
Pure heavy-bedded limestone	10–60
Cherty limestone	20–60
Limestone and sandstone	200+
Clinton (Rockwood) formation	150+

Near the surface the rocks are all disintegrated except the "Monterey" (Oriskany) sandstone and here and there the cherty portion of the Lewistown limestone. At greater depth the disintegration is confined to the portions of the rocks near the contact of the ore deposits. In general the ores lie on clay containing numerous fragments of chert and are overlain by a dark-colored sandstone or by blue clay. Locally where the middle portion of the Lewistown limestone is very cherty it has remained undecomposed, and in such places the ores rest on a solid, uneven bed of chert, as at the old Rich Patch workings. The foot wall is considerably stained by iron, many of the chert masses being covered with a dark-brown or red coating. The "Monterey" sandstone contains numerous small veins of limonite and portions of it are largely replaced by iron. Where it is absent the ore bodies are overlain directly by a few feet of dark-colored plastic clay derived largely from the overlying shales. The shales are black and contain a considerable percentage of iron. They are solid and

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undecomposed within a few feet of the ore body. Where the "Monterey" sandstone is present the blue clay apparently occurs between it and the overlying shale. The mixture of chert and clay on the foot wall has a variable thickness and when it is penetrated the solid cherty limestone is found underneath. Locally a lens of chert may be interbedded with an ore deposit and divide it into two limbs. This was probably originally cherty limestone interbedded between two layers of pure limestone.

At a considerable depth, perhaps about 300 or 400 feet, the ore deposit begins to get thinner and limestone appears on both hanging and foot walls until finally, at a reported depth of about 600 feet, the ore gives place to solid limestone.

The ore deposits vary in thickness from a few feet to 75 feet, with an average of about 15 to 25 feet. They may extend along the strike of the formations in a series of pockets for half a mile or more, in which distance there is generally a great variation in thickness, and locally the deposit may pinch out altogether.

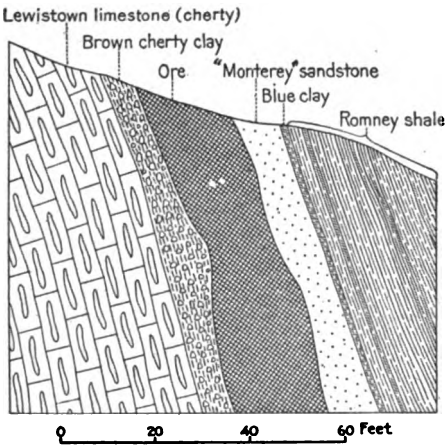

FIGURE 22.—Vertical section showing the structure of the Oriskany brown ore deposit at the Wilton mine, near Glen Wilton, Va.

The principal Oriskany brown ore mines in Virginia are the Liberty and Van Buren Furnace mines, in Shenandoah County; the Buffalo Gap and Ferrol mines, in Augusta County; the Victoria and Longdale mines, north of Longdale, Alleghany County; the Dolly Ann, Iron Mountain, and Stack mines, near Covington, Alleghany County; the Low Moor and Rich Patch mines, near Lowmoor, Alleghany County; the Jordan mines, on Potts Creek, Alleghany County; the Callie, Wilton, and Circle mines, near Glen Wilton, Botetourt County; the Oriskany and Fenwick mines, in Botetourt and Craig counties, near Oriskany; the Gala mines, near Dagger Springs, Botetourt County; the Clayton and Peak Knob mines, near Pulaski, Pulaski County; and the Locust Hill mine, near Max Meadows, Wythe County.

Character and origin of the ore.—The Oriskany ores are very similar to the mountain ores in that they are high in silica and manganese. The phosphorus content in general ranges between that in the mountain and that in the valley ores. Most of the ore is dark brown and amorphous, and much of it contains sand grains and partly replaced clay. Needle ore occurs in cavities, but it is not very abundant.

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Fragments and porous masses of chert are common associates of the ore, representing unreplaced portions of the original limestone bed. The ore is usually hard and solid, but locally porous and cellular masses are found, and these contain clay in the cavities.

The iron content of the Oriskany ores ranges between 35 and 50 per cent. The phosphorus ranges from 0.06 to 0.5 per cent, silica from 10 to 25 per cent, and manganese up to 3 or 4 per cent. The following table gives analyses of Oriskany iron ores (see also analysis 8, p. 222):

Analyses of Oriskany iron ores from Virginia.[a]

	1.[b]	2.[c]	3.[c]	4.[c]	5.[c]	6.[c]	7.	8.[c]	9.	10.[c]	11.	12.[c]
Fe	41.10	43.90	35.26	40.14	41.51	46.19	44.32	51.77	48.20	51.66	45.67	43.71
SiO_2	16.32	.....	.....	21.58	.....	.....	.....	.....	.....	9.97	.....	.....
Insoluble	.....	.....	.....	.....	.....	.....	24.15	.....	13.83	.....	19.72	.....
P	.35	.076	.066	.36	.310	.289	.....	.428	.42	.463	.....	.380
Mn	3.40	.....	.....	1.06	.....	.....	.....	.....	.....	.....	.....	.....

	13.	14.[c]	15.	16.	17.[c]	18.[c]	19.	20.	21.	22.[b]	23.[b]	24.[c]
Fe	46.52	43.84	42.90	41.10	45.62	37.39	45.88	40.37	44.60	41.12	53.46	37.54
SiO_2	.....	22.87	25.60	.....	.....	.....	.....	.....	22.30	.....	4.58	18.79
Insoluble	17.60	.....	.....	24.41	.....	.....	16.29	21.81	.....	.....	.....	.....
P	.....	.636	.33	.43	.067	.395	.12	.48	.....	.....	1.22	.34
Mn	.....	.....	.78	.69	.....	.....	2.18	.69	.....	.51	.40	1.55

[a] Analyses 1, 4, 7, 9, 11, 13, 15, 16, and 19 to 24 from Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, pp. 431–459. Analyses 2, 3, 5, 6, 8, 10, 12, 14, 17, and 18 from Benton, E. R., Iron-ore mines of Virginia: Tenth Census, vol. 15, Mining industries, 1886, pp. 279–288.

[b] Dried at 212° F.

[c] Natural state.

1. Liberty mine, near Liberty Furnace, Shenandoah County. Analysis by Shenandoah Iron and Coal Co.
2. Hollow Bank, near Liberty Furnace, Shenandoah County. Analysis by F. A. Gooch.
3. West mine, near Van Buren Furnace, Shenandoah County. Analysis by F. A. Gooch.
4. Pit Spring mine, near Shenandoah, Page County. Analysis by Alleghany Ore and Iron Co.
5. Buffalo Gap mine, near Buffalo Gap, Augusta County. Analysis by F. A. Gooch.
6. Ferrol mine, near Ferrol, Augusta County. Analysis by F. A. Gooch.
7. Dolly Ann mine, near Covington, Alleghany County. Analysis by Low Moor Iron Co.
8. Dolly Ann mine, near Covington, Alleghany County. Analysis by F. A. Gooch.
9. Longdale mines, near Clifton Forge, Alleghany County. Analysis by Longdale Iron Co.
10. Longdale mine, near Clifton Forge, Alleghany County. Analysis by F. A. Gooch.
11. Stack mine, near Covington, Alleghany County. Analysis by Low Moor Iron Co.
12. Stack mine, near Covington, Alleghany County. Analysis by F. A. Gooch.
13. Low Moor mine, near Lowmoor, Alleghany County. Analysis by Low Moor Iron Co.
14. Low Moor mine, near Lowmoor, Alleghany County. Analysis by F. A. Gooch.
15. Rich Patch mine, near Lowmoor, Alleghany County. Analysis by Goshen Iron Co.
16. Potts Valley mine, near Covington, Alleghany County. Analysis by Alleghany Ore and Iron Co.
17. Callie mine, near Glen Wilton, Botetourt County. Analysis by F. A. Gooch.
18. Wills mine, near Covington, Alleghany County. Analysis by F. A. Gooch.
19. Oriskany mine, near Lignite, Botetourt County. Analysis by Alleghany Ore and Iron Co.
20. Ried mine, near Oriskany, Botetourt County. Analysis by Alleghany Ore and Iron Co.
21. Fenwick mine, in Craig County, near Oriskany. Analysis by Low Moor Iron Co.
22. Clayton mine, near Pulaski, Pulaski County. Analysis by Pulaski Iron Co.
23. Peak Knob mine, near Pulaski, Pulaski County. Analysis by New River Mineral Co.
24. Locust Hill mine, near Max Meadows, Wythe County. Analysis by Virginia Iron, Coal and Coke Co.

The iron composing the Oriskany ores is derived from the overlying Devonian shales, which are black and very rich in iron minerals. Upon weathering the shales are decomposed and the iron is carried

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downward in solution by meteoric waters. The solutions have penetrated the underlying "Monterey" (Oriskany) sandstone, in which iron oxide has been deposited along fractures and has abundantly replaced the cement between the sand grains. Where the sandstone is sufficiently thin and fractured the solutions have penetrated into the underlying Lewistown limestone, and have replaced the calcium carbonate by ferric oxide, and thus formed iron-ore deposits. The extent to which the limestone is replaced depends on its purity; only the upper pure beds are replaced, the lower cherty beds being stained and partly decomposed. It is only where the layers have a moderately shallow dip that downward-moving waters can reach the limestones, and so the ores are confined largely to localities where such structural conditions prevail. Where the strata are steep or overturned ore deposits are rare.[a]

That the solution and deposition of iron is still going on is shown by the fact that waters percolating through the Romney shale carry an abundance of iron which is deposited as limonite on the walls of tunnels and drifts cutting the shale. This is especially noticeable at the Wilton mine, near Glen Wilton, Botetourt County.

Favorable conditions for the formation of Oriskany ores therefore are (1) nearness to the surface, (2) a thin and fractured bed of "Monterey" (Oriskany) sandstone, (3) a thick bed of pure limestone immediately underlying the sandstone, and (4) a moderately shallow dip of the beds.

LIMESTONE MAGNETITE ORES.

Limestone magnetite deposits[b] occur in the upper formations of the Shenandoah group and in clays derived from them. The principal deposits are found near Big Stony Junction, Giles County, and near Abingdon, Washington County; smaller deposits occur elsewhere in the southwestern part of the State. In Washington County the deposits are near the top of the Chickamauga limestone, not far from the border of an area of Athens shale. The ore consists of magnetite and hematite, the former in many places making up a dark steel-gray skeleton in which earthy red hematite fills the interstices. Locally in the limestone iron carbonate superficially altered to limonite is associated with the magnetite and hematite. The magnetite usually occurs as beds in the limestone and in lumps of a few pounds each in the clay and is farther from the surface than the associated minerals. It is of high grade.

So far as present developments show, the deposits are small, being only a few rods in extent and about 30 feet deep, though indications

[a] Johnston, J. E., jr., The origin of the Oriskany limonites: Eng. and Min. Jour., vol. 76, 1903, p. 231.

[b] Holden, R. J., Iron, in Watson, T. L., Mineral resources of Virginia, 1907, p. 422.

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of ore occur over a wider area. Holden believes that these ores are secondary concentrations from the overlying shale.

The following table gives analyses of limestone magnetite:

Analyses of limestone magnetite from southwestern Virginia.[a]

	1.	2.	3.	4.	5.
Fe	63.55	48.82	58.30	56.05	62.00
SiO_2 or insoluble	5.21	19.76	.....	7.76	5.50
P	.05	.05	.027	.036	.02
S	.002	.16	.....	.06	
Mn	.....	.....	.....	None.	Trace

1. Johnson mine, near Big Stony Junction, Giles County. Analysis by A. S. McCreath.
2. Porterfield mine, near Riffleмead, Giles County. Analysis by A. S. McCreath.
3. Semi-Magnetic mine, near Wytheville, Wythe County. Analysis by F. A. Gooch.
4. Galleher mine, near Abingdon, Washington County. Analysis by A. S. McCreath.
5. Holston mine, near Abingdon, Washington County. Analysis by Ivanhoe Furnace Co.

IRON CARBONATE.

Iron carbonate occurs sparingly in Virginia, being present in minable quantities at only one locality, near Abingdon, Washington County.[b] Here it occurs in a brecciated zone in the Chickamauga limestone near the border of the overlying Athens shale. It is associated with the limestone magnetite deposits and is superficially altered to limonite. At a few localities ironstone concretions occur abundantly in the Romney and Martinsburg shales.

The following is an analysis of iron carbonate associated with limestone magnetite:

Analysis of iron carbonate from Holston mine, near Abingdon, Washington County, Va.[b]

[By Ivanhoe Furnace Co.]

Fe	35.00
Insoluble	7.00
P	.03
CaO	12.00
MgO	5.00

PYRITE DEPOSITS.

Pyrite occurs in disseminated form in most of the Cambrian formations, but has been found in workable deposits only in the Shady limestone in the New River district. Here it occurs in separate deposits and also in association with lead and zinc sulphides. The pyrite is used in the manufacture of sulphuric acid, like pyrrhotite, and the iron oxide residuum is sent to the blast furnaces to be used

[a] Analyses 1, 2, 4, and 5 from Holden, R. J., op. cit., pp. 447–448, 461–462. Analysis 3 from Benton, E. R., Iron-ore mines of Virginia: Tenth Census, vol. 15, Mining industries, 1886, p. 277.
[b] Holden, R. J., op. cit., p. 462.

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in the manufacture of pig iron. Little or no pyrite is being mined in the New River district at the present time.

THE IRON INDUSTRY IN VIRGINIA.

In 1907 Virginia ranked as the ninth State in the production of iron ore, producing a total of 786,856 tons, of which 696,518 tons was brown ore, 89,867 tons hematite, and 471 tons magnetite. These figures illustrate the relative importance of the different classes of ores. The brown ores are derived largely from the Alleghany County region and the New River district. In the Blue Ridge region only six mountain brown ore mines and four specular hematite mines are in operation. In the New River region 25 mines or more are producing brown ore, about two-thirds of this number operating on valley ore deposits and the rest on mountain ores. About a dozen mines are producing Oriskany ores, all except one or two of these being in Alleghany County and vicinity, in west-central Virginia.

Nearly all the ore mined is used in local furnaces, all except four or five mines being worked by mining companies who operate their own furnaces. The following are the principal mining companies:

The Virginia Iron, Coal and Coke Company has specular hematite and brown-ore mines near Blue Ridge Springs and Roanoke, brown-ore mines in the New River district, and fossil hematite mines in the Lee and Wise county area. Its furnaces are at Bristol, Washington County; Roanoke, Roanoke County; Pulaski, Pulaski County; Graham, Tazewell County; Max Meadows, Wythe County; Radford, Montgomery County; Foster Falls, Wythe County; and Reed Island, Pulaski County. The last two are charcoal furnaces; all the others are coke furnaces.

The Oriskany Ore and Iron Company has brown-ore mines at Vesuvius and in the Alleghany County district and coke furnaces at Iron Gate, Alleghany County; Buena Vista, Rockbridge County, and Shenandoah, Page County.

The Low Moor Iron Company has fossil hematite and brown-ore mines in the Alleghany County district and coke furnaces at Low Moor and Covington, Alleghany County.

The Pulaski Iron Company has a specular hematite mine near Buchanan and brown-ore mines in the New River district. It has coke furnaces at Pulaski, Pulaski County.

The Ivanhoe Furnace Company has brown-ore mines in the New River district and a coke furnace at Ivanhoe, Wythe County.

The Longdale Iron Company has brown-ore mines in the Alleghany County district and coke furnaces at Longdale, Alleghany County.

The Princess Furnace Company has brown-ore mines and a coke furnace at Glen Wilton, Botetourt County.

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The Goshen Iron Company has brown-ore mines at Buena Vista and in the Alleghany County district and a coke furnace at Goshen, Rockbridge County.

The West End Furnace Company has brown-ore mines in the New River district and a coke furnace at Roanoke, Roanoke County.

The Union Iron and Steel Company has fossil hematites in the Lee and Wise County district and a coke furnace at Big Stone Gap, Wise County.

Besides the companies above named there are a few mining companies not at present operating who own charcoal or coke furnaces, and a few companies who do not own furnaces but are operating mines and selling their ore.

The above-named companies as a rule operate their own limestone quarries, from which flux for the furnaces is obtained, and a few companies also own coal mines. Limestone suitable for flux is plentiful throughout western and southwestern Virginia and is generally quarried near the furnaces. Fuel is shipped in from the neighboring coal fields.

The Oriskany ore deposits give greater promise than the other iron deposits of Virginia because of their extent, continuity, and depth, combined with the fact that they yield a fair grade of ore. Numerous deposits probably remain to be discovered, and it may be pointed out that the regions most favorable for exploitation are the Massanutten Mountain district and the area to the southwest of Alleghany County, with adjacent parts of West Virginia.

The valley ores, which are second in importance to the Oriskany ores, have probably reached their greatest development. Few new deposits remain to be discovered, and the productive capacity of most of those which are being operated is already on the decline. Considerable areas are being left unworked because the proportion of the ore to clay is so low that they can not now be mined at a profit. It is probable that in the future such deposits may be profitably worked, and if they are, large areas will become available.

The mountain ores for the most part occur in small discontinuous deposits. In many places a number of such deposits are grouped together and become of commercial importance. The mountain ore deposits along the Blue Ridge have been worked on a small scale for many years, but they have been found to be unreliable. This fact, together with the somewhat low grade of the ore, is preventing their development. A few deposits, however, are being operated regularly and are yielding good returns, and others are being worked intermittently. The mountain ores of the New River district, though of low grade, appear to be more continuous than those of the Blue Ridge and here eight or ten deposits are being worked regularly.

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The hematite deposits, which constitute the other important class of iron ores of Virginia, are of moderate extent. The fossil hematite, though of good grade, generally occurs in beds which are too thin to be mined at a profit, and where beds of sufficient thickness occur they are not very extensive. At present a number of mines in Lee and Wise counties and the Horse Mountain mine, in Alleghany County, are being operated. The specular hematite beds are of considerable thickness and are of greater extent than the fossil ore beds. They would be of great value if composed of high-grade ore, but unfortunately the ore is very siliceous and can be used in furnaces only with great difficulty without the addition of other ores. Three or four mines, however, have been producing this ore regularly for a number of years, and the furnaces are using it in connection with brown ore.

The valley ores are mined exclusively from large open cuts, but the mountain and Oriskany ores are mined both from open cuts and from underground workings, the former method generally preceding the latter in the history of a mine. Specular and fossil hematite ores are mined from stopes and underground workings.

All the brown ores require washing and concentrating in order to free them from associated clay, sand, gravel, and rock fragments. The ore as it comes from the mines is crushed into fragments an inch or two in diameter and sent through a series of log washers. In these most of the clay is removed, and after passing through them the mixture of ore and rock fragments is screened so as to separate the small from the large fragments. The small pieces are cleaned by sending them through concentrating jigs; the large ones are passed over picking belts or tables, and the rock fragments are removed by hand picking. The jigs are far from perfect and allow a considerable quantity of rock fragments to pass through, thus lowering the grade of the ore. This is especially true in the case of mountain ores, in which gravel and rock fragments are more abundant than in the other varieties. Specular and fossil hematite ores are supplied to the furnaces in the form in which they come out of the mines, without preliminary concentration.

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MANGANESE DEPOSITS OF THE UNITED STATES.

By E. C. HARDER.

INTRODUCTION.

In the winter and spring of 1908 the writer made an examination of the principal manganese districts in the United States and during the summer prepared a general report on manganese,[a] which will soon be ready for publication. The present paper is a brief digest of the principal portions of that report.

The manganese mining industry of the United States has been on the decline during recent years, owing to the extensive importation of high-grade ores from India, Brazil, Cuba, and the East Indies. The average grade of the domestic ores is much lower than that of the imported ores and they require considerable treatment, such as washing and sorting, to prepare them for the market. Besides, the domestic ores occur mostly in small scattered pockets, whereas the foreign ores are found in extensive beds and large deposits. All these circumstances have decreased the demand for the American manganese ore.

SOURCES OF MANGANESE.

Manganese has been obtained from four different classes of materials in the United States—manganese ore, manganiferous iron ore, manganiferous silver ore, and manganiferous zinc residuum.

Manganese ores may consist of any of the oxides or of the carbonate of manganese, but only the oxides occur in commercial quantities in the United States. Pyrolusite and psilomelane are by far the most important. Wad and braunite are of some importance, but manganite is rare. Pyrolusite has a theoretical manganese percentage of 63.2 and psilomelane of 45 to 60. As they occur in nature, however, the ores generally range from 40 to 50 per cent in metallic manganese. Psilomelane and pyrolusite are usually intermingled, being generally found as nodular concretions in which the two minerals form concentric layers, the psilomelane being amorphous and the pyrolusite

[a] Harder, E. C., Manganese deposits of the United States; with sections on foreign deposits, chemistry, and uses: Bull. U. S. Geol. Survey (in preparation).

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occurring in small parallel needles. In many places nodules of pure pyrolusite occur with similar concentric layering, the successive layers being made up of granular and crystalline or needle-like pyrolusite. Pyrolusite and psilomelane locally have small admixtures of iron oxides and such ores are used in the steel industry. When free from iron they are very desirable for oxidizing and coloring purposes, but are extensively used in the steel industry also.

Deposits of manganese ore occur in many parts of the United States, but are most abundant in the Appalachian and Piedmont regions, in the southern Mississippi Valley, and on the Pacific coast. Small deposits occur in the New England, Rocky Mountain, and Great Basin regions. The principal producing districts up to the present time have been the James River valley and Blue Ridge regions in Virginia, the Cave Springs and Cartersville districts in Georgia, the Batesville district in Arkansas, and the Livermore-Tesla district in California. Of minor importance are the New River region in Virginia, the northeastern Tennessee region, the McCormick area in South Carolina, and the Little Grande district in Utah. Besides these there are minor deposits in many parts of the country which have produced small quantities of ore intermittently. During recent years operations have been confined to the Blue Ridge region, the James River valley, the northeastern Tennessee region, the McCormick area, and the Livermore-Tesla district. The manganese ore produced at present is being used in the manufacture of spiegeleisen and ferromanganese, and as a coloring material for bricks, pottery, and other articles.

Manganiferous iron ores consist of a mixture of any oxide or the carbonate of iron with any oxide or the carbonate of manganese. In this country manganiferous iron ores consist largely of limonite or hematite mixed with psilomelane, wad, or pyrolusite, a mixture of limonite and psilomelane being the most common. The iron and manganese oxides may be intimately intermingled or they may be coarsely mixed, so as to be easily distinguished from each other. In places good-sized pockets of manganese ore occur in deposits of iron ore, which are otherwise free from manganese. High-grade manganiferous iron ores are used in the manufacture of spiegeleisen and ferromanganese. Most of the low-grade manganiferous iron ores are not utilized for their manganese, which is generally considered an undesirable constituent.

Manganiferous iron ores occur in the United States chiefly in the New England, Appalachian, and Lake Superior regions, but minor deposits are found in the southern Mississippi Valley and in the Rocky Mountain region. High-grade manganiferous iron ore occurs in the Appalachian region, but there has been only a small production

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in recent years, the principal manganiferous iron ores produced at present being low-grade ores from the Appalachian and Lake Superior districts, which are so low in manganese that they are classed as iron ores. In the blast furnace they yield a "high-manganese" pig iron which is used for special purposes.

Manganiferous silver ores consist of a mixture of manganese and iron oxides, with small amounts of silver sulphide and lead carbonate, and in some places of gold. As a rule the iron content exceeds the manganese content, though here and there manganese may be in excess and rarely it may replace the iron altogether. These ores occur as a capping or gossan above metalliferous sulphide deposits which consist largely of iron, lead, zinc, and silver sulphides in a gangue of quartz or calcite. Locally rhodonite and rhodochrosite are present in the unaltered ores.

Manganiferous silver ores are divided into four classes, according to their uses. The greater portion of the ores are used for their silver and lead content. The manganese and iron content often insures these ores a higher price because of their fluxing value. The second class of manganiferous silver ore is too low in silver and lead to be used as a source of these metals, but is sufficiently high in manganese and iron to be used for the manufacture of ferromanganese and spiegeleisen, like the high-grade manganiferous iron ores mentioned above. At some localities the ore of this class is too low in manganese to be used in the manufacture of iron-manganese alloys and is used simply as an iron ore, like the low-grade manganiferous iron ores. A fourth class of manganiferous silver ore is too low in silver and lead to be used primarily for these metals and too low in iron and manganese to be used for the manufacture of iron-manganese alloys. This ore is sold to the smelters as flux, the iron and manganese becoming waste products, while the silver and lead content is recovered during the smelting.

Manganiferous silver ores occur in the Rocky Mountain and Great Basin regions, the principal producing localities being Leadville, Colo., and Tintic, Utah. Some of the Leadville ores are used in the manufacture of spiegeleisen. All the other localities produce these ores for fluxing only.

Manganiferous zinc residuum is obtained from zinc volatilizing and oxidizing furnaces using New Jersey zinc ores. The residuum consists largely of iron and manganese oxide, the zinc having been removed by volatilizing and collected as zinc oxide. The crude ores consist of franklinite, zincite, and willemite and are obtained only from the Franklin furnace district, in New Jersey. Small quantities of zinc residuum are used annually in the manufacture of spiegeleisen.

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DISTRIBUTION AND OCCURRENCE OF THE ORES.

MANGANESE ORES.

VERMONT.

Manganese ore occurs near the towns of South Wallingford and Brandon, in Otter Creek valley, Vermont. In both localities the deposits are on the west slope of the Green Mountains at or near the contact of a lower Cambrian quartzite, which forms ridges along the west slope, and an overlying limestone of approximately the same age, which underlies the valley to the west. The deposits are mainly brown iron ore, with subordinate manganese.

The South Wallingford deposit[a] consists of pockets of iron and manganese ores, occurring separately or mixed in all proportions. The manganese ore is massive black psilomelane, with nests of crystalline pyrolusite. The ore occurs at intervals in a bed of yellow, red, and variegated clays at the contact of the quartzite and the limestone. The bed is almost vertical, dipping slightly to the west, and has a strike a little east of north. It has a probable average thickness of several hundred feet.

The Brandon deposit[b] is composed mainly of brown iron ore and subordinately of manganese ore in brown and white surface clays adjacent to the limestone-quartzite contact. In similar clays in the same locality lignite and Tertiary fossils have been found; hence it seems possible that the ore-bearing clay is a surface deposit derived from an underlying clay bed equivalent to that found at South Wallingford. The manganese ore is mainly in the form of black amorphous psilomelane kidneys, in some places containing nests of pyrolusite crystals. These kidneys are of various sizes and occur in pockets scattered through the clay, being locally associated with masses of iron ore.

VIRGINIA.

Manganese deposits occur in Virginia in the Piedmont region and in the Appalachian Valley.

The ore of the Piedmont region occurs in the James River valley northeast and south of Lynchburg. There are a number of old mines in this district, but only that of the Piedmont Manganese Company, near Mount Athos, and the Theresa mines, near Otter River, are at present producing ore. The deposits occur in residual clay and sand derived from ancient crystalline rocks. This material is still in place, and much of it is only partly decomposed, so that the texture and structure of the original rocks are clearly distinguishable. In general the ore occurs in nodular masses, ranging in weight up to

[a] Penrose, R. A. F., jr., Manganese: Ann. Rept. Arkansas Geol. Survey, 1890, vol. 1, p. 392.
[b] Idem, p. 395.

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500 pounds and scattered through a yellowish-brown micaceous clay forming a nearly vertical layer between decomposed granite and quartzose mica schist residuum. The original nature of this ore-bearing layer is unknown.

The Piedmont Manganese Company's mine is situated on Beaver Creek, in Campbell County, about 1½ miles southeast of Mount Athos. In the present workings the ore occurs in masses in a yellow and brown micaceous clay bed dipping steeply to the southeast and having a general northeast-southwest strike. This layer is between a decomposed granite on the hanging wall and a residual micaceous clay on the foot wall. The latter is very similar to the ore-bearing clay and grades into it, the ore increasing in quantity toward the granite contact. The hanging wall also grades into the ore deposit through a zone partly replaced by manganese oxide. The ore-bearing layer, as exposed, varies from 5 to 10 feet in thickness, but ore apparently occurs at intervals for 50 feet from the hanging-wall granite. In places the ore masses are closely grouped, and the clay forms a very small part of the bed; elsewhere the clay may make up more than half of the layer. The length of the deposit is not known, but surface outcrops occur at intervals along the strike for a quarter of a mile to the northeast. The presence of ore-bearing layers parallel to the one now worked has been shown by surface pits.

In general the same conditions prevail in the old, unworked mines of the district. In the Leets mine, about 1½ miles northeast of the Piedmont Company's mine, ore occurs in a similar brownish-yellow micaceous clay between decomposed granite and schist and as a replacement of the adjacent part of the granite. Surface workings on the Saunders property, 2 miles east of Evington, show nodular ore in a red and yellow residual clay having a decomposed mica schist as foot wall. In the Cabell and Piedmont mines, about 2 miles north of Warminster, granite and schist are again to be seen, but their relations are somewhat obscured by the age of the workings.

A characteristic associate of many manganese deposits in the Piedmont region is a manganese-stained earth or clay known as "umber," which is a residuum of some formation as yet unknown. Crystalline limestone[a] has been found with it and may be a clue to its origin as well as to the origin of the deposits.

The Appalachian Valley may be conveniently divided into two districts, the Blue Ridge region and the New River region. The chief deposits of the Blue Ridge region occur on the west slope of the ridge from Front Royal on the north to Roanoke on the south. Through this area manganese deposits are found at irregular intervals near the foot of the mountains. The same region includes the Blue Ridge iron-ore mines, many of which contain some manganese ore, locally

[a] Watson, Thos. L., personal communication.

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in such quantity as to form a manganiferous iron ore. Similarly, most of the manganese deposits contain some iron, especially near the surface.

The Blue Ridge extends along the contact between the ancient crystalline rocks of the Piedmont region and the Paleozoic sediments. The latter, although nearly vertical, have a general westward dip on the west slope of the mountains. The following section shows the succession of formations:

Section for the middle valley of Virginia.

Ordovician: Natural Bridge limestone.
Cambrian:
"Buena Vista" shale.
Sherwood limestone.
Lower Cambrian quartzite (contains manganese).
Lower Cambrian shale and quartzite (not manganese bearing).
Pre-Cambrian: Crystalline and metamorphic rocks.

The lower Cambrian quartzite occupies the main west slope of the mountains; the Sherwood limestone (believed to be the same as the Shady limestone farther south) and "Buena Vista" shale (believed to be the same as the Watauga shale farther south) lie on a gently sloping bench at the base; and the Natural Bridge limestone occurs in the valley to the west.

The manganese deposits occur in the limestone area near the contact with the underlying quartzite. With a few exceptions they are pockets of local concentration occurring in residual clay. With regard to texture the ore is of four varieties: (1) Kidneys of black psilomelane embedded at intervals in clay. (2) Irregular masses, many of them porous, of psilomelane with numerous layers or nests of crystalline pyrolusite, embedded in clay. This form is commonly assumed by local ore segregations in a manganiferous clay. (3) Breccia ore in large masses, consisting of sandstone or chert fragments, with either psilomelane or pyrolusite as cementing material. (4) Replacement and cavity fillings in sandstone or sandy clay. The ore of this type is composed largely of crystalline and granular pyrolusite with associated psilomelane.

The manganese ores are widely distributed along the Blue Ridge ore belt, but it is only here and there that they are sufficiently concentrated to form a workable deposit. In such deposits there are alternating layers, lenses, or irregular bodies of barren and ore-bearing clays. In many places one body of clay carries ore of a certain type, and an adjacent mass carries ore of another type. Of the numerous mines along this belt only the Dry Run, Crimora, Lyndhurst, and Vesuvius mines are at present in operation.

The Dry Run mine has recently been opened on an old manganese tract about 1 mile south of Compton, Page County. The ore is

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largely psilomelane in botryoidal forms occurring as cement in a brecciated pocket in solid lower Cambrian quartzite. Quartzite fragments form the principal part of the deposit, the manganese ore seams between them varying in width up to 3 or 4 inches. Cavities lined with botryoidal forms are numerous.

The Crimora mine is in Augusta County, about 2 miles east of Crimora station, on the Shenandoah Valley division of the Norfolk and Western Railway. The ore deposit is located in an elliptical basin in a canoe-shaped syncline of the lower Cambrian quartzite. The basin has a general north-south trend and is about a half a mile long, a few hundred yards wide, and about 200 feet deep. It is filled with yellow, red, and variegated clays. The ore is hard and of three varieties—(1) kidney ore of black psilomelane, (2) replacement and cavity fillings of psilomelane and pyrolusite in sandy clay, and (3) irregular pockets in manganiferous clays. The ore masses are segregated in local layers, lenses, and irregular bodies of clay, separated by barren areas. Near the surface the ore is somewhat ferruginous. In the eighties and early nineties the Crimora mine consisted mainly of underground workings. About 1895 these were abandoned and operations were begun for a system of hydraulic mining. A tunnel over a mile in length was cut westward from the lower part of the basin through the western rim, thus draining the entire basin above it. Water was brought to the mine by flumes from several points in the surrounding mountains. This system, however, has never been put fully into operation. The Crimora mine at present consists of a large open pit, near the center of which there is a shaft connecting with the long drainage tunnel. Operations are conducted on a very small scale and consist in taking out the ore left between the old levels. There is still about 135 feet of workable ground left between the bottom of the pit and the level of the tunnel, and nearly half of this is untouched by former workings.

The Lyndhurst mine is in Augusta County, about 2½ miles south of Lyndhurst, on the Shenandoah Valley division of the Norfolk and Western Railway. This deposit consists of scattered kidneys and irregular masses in clay. The former occur in small, irregular nodules averaging an inch or two in diameter, but in places reaching 5 or 6 inches. They are scattered through horizontal layers or lenses of red, brown, and variegated clays at intervals of a few inches to a foot or more. Mingled with the light-colored clays are layers and lenses of dark manganiferous clays which contain the ore of the second type. This varies from seams to irregular masses of different sizes and is either hard or soft. The ore is scattered at irregular intervals in a pocket which has been tested to a depth of about 60 feet and for a horizontal extent of about 300 yards. On account of the scattered location of the ore masses, much dirt has to be washed

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to get a small quantity of ore. The extent of the deposit, however, seems to be such as to warrant this expense. The mine consists of several shafts, with drifts at five levels.

The Vesuvius mine also is in Augusta County, about 1½ miles northeast of Vesuvius. The deposit is in a pocket, whose extent has not yet been determined, at the foot of the Blue Ridge. The workings consist of some old open pits, a shaft with underground workings recently abandoned, and a new shaft started west of the old workings. The ore is of two varieties—(1) breccia ore, occurring in large masses, with chert or sandstone fragments and either psilomelane or pyrolusite as cement, and (2) kidneys of ore from 3 to 6 inches in diameter, embedded in clay. Many of the breccia ore masses have a thick coating of botryoidal psilomelane.

Besides the mines mentioned, there are many unworked mines in this belt. Among them are the Fronk property near Kimball, Page County; the Eureka Manganese mine, southwest of Stanleyton, Page County; the Kimball mine and Garrison bank, east of Shenandoah, Page County; the Kendall and Flick mines, near Elkton, Rockingham County; the Seller mine, near Islandford, Rockingham County; the Shaver mine, near Port Republic, Rockingham County; the Old Dominion mine, which occupies the southern part of the Crimora basin, Augusta County; the Watt property, east of Dooms Crossing, Augusta County; the Kennedy and Mount Torry tracts, east of Stuarts Draft, Augusta County; the Midvale mine, east of Midvale, Rockbridge County; the Gowen and White banks, southeast of Lithia, Botetourt County; and the Houston banks, northeast of Troutville, Botetourt County. The ore deposits in Page and Rockingham counties all contain considerable brown iron ore. The manganese is largely in the form of nodular psilomelane, as at the Eureka Manganese and Kendall and Flick mines, but soft granular pyrolusite is common, as at the Fronk property, Kimball mine, and Garrison bank. The ore mined on the Old Dominion property has been mainly ferruginous surface ore. At a greater depth ore similar to that found in the Crimora mine will probably be obtained. The ore on the Watt property consists of masses of mixed psilomelane and pyrolusite with sandy clay fragments. On the Mount Torry and Kennedy properties the surface ore consists of ferruginous botryoidal and porous masses. The Kennedy open pit contains psilomelane kidneys near the bottom. The Gowen bank contains soft, blue ore; and the manganese ore shown in the Houston banks is mainly blue granular pyrolusite occurring as seams and replacements in sandstone horses. Some irregular masses of psilomelane and pyrolusite occur in the clays together with brown iron ore. Besides the occurrences noted above both manganese and manganiferous iron are

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found in most of the iron-ore mines. The deposits at some of the latter, like Mine Bank, 6 miles northeast of Vesuvius, consist almost entirely of manganiferous iron ores; at others, like the Happy Creek mine, near Front Royal, Warren County, they consist largely of iron ore, but the mines produce intermittently small quantities of manganese ore.

The manganese deposits of the New River region occur in several belts south of Pulaski, Wytheville, and Marion. The ores are found in the lower part of the Shady limestone and the upper part of the underlying Erwin quartzite, and almost invariably iron ores are associated with them. In the deposits visited the ores do not seem to have the form of kidney-shaped bodies, which are so prevalent elsewhere in Virginia, but rather to occur in large, porous masses, containing varying quantities of brown iron ore and much included clay and sand. Very little ore has been produced in this district, most of it coming from the Umbarger and the Currin Valley mines, southeast of Marion.

The Umbarger mine is about 1½ miles east of Sugar Grove, Smyth County. The main ore deposit consists of large masses of mixed porous psilomelane, limonite, and sandy clay. These masses range in size up to 6 or 8 feet, are of irregular shape, and occur in yellow or red clays. Ore has been taken out from a few cuts near the surface. Some ore is also scattered through a considerable area as small, irregular nodular masses, mainly psilomelane with some included pyrolusite, in yellow and red clay.

The Currin Valley mine is about 1½ miles south of Attoway, Smyth County. The workings consist of a large open pit from which considerable brown iron ore has been taken. The ore is in large masses and is a mixture of manganese ore, brown iron ore, and sand or clay, occurring locally in variegated clay. Manganese ore is also present at the Atkins mine, southeast of Attoway; on the Walker and Tate properties, north of Sugar Grove; at the Eagle Cliff mine, near Ivanhoe, Wythe County; near Allisonia, Pulaski County; and at several localities south of Wytheville.

Manganese ore is found outside of the three districts mentioned at several localities in Virginia, among which are some in the Oriskany iron-ore area in Shenandoah and Frederick counties, near Seven Fountains and Cedar Creek. Small deposits associated with Oriskany iron ores occur near Dagger Springs, Botetourt County, and at other localities to the southwest.

TENNESSEE.

The manganese ores of Tennessee are the southward continuation of the Appalachian Valley deposits of Virginia. As in Virginia, they

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occur near the eastern border of the valley. The best known of the Tennessee deposits occur in the vicinity of Newport and Del Rio, Cocke County; near Unicoi, Unicoi County, and in Shady Valley, Johnson County.

The Yellow Springs mine on English Mountain, 5 miles southwest of Newport, consists of an open pit in brown and red clays and sand, residual material derived from a lower Cambrian quartzite. Both soft and hard ores are present, the former generally occurring in irregular pockets and seams associated with manganiferous clays, and the latter in small kidneys and irregular masses scattered through the clay and the soft-ore pockets. There are numerous surface indications of manganese for several miles east of this mine, but little or no development work has been done.

The ore deposits at Del Rio and near Unicoi were not visited, but are reported to have similar associations.

In Shady Valley [a] manganese deposits occur associated with brown iron ore in residual clays probably derived from the Shady limestone. They are situated in the northern part of the valley, north of Cross Mountain.

Irregular masses of granular blue pyrolusite occur with iron ores in residual red clays of the Knox dolomite about 1½ miles northeast of Sweetwater, Monroe County.[b]

NORTH CAROLINA AND SOUTH CAROLINA.

In North and South Carolina manganese ores occur in two districts—the Kings Mountain region, on the boundary of the two States, and the McCormick area, Abbeville County, S. C. In the Kings Mountain district manganese oxides occur as stains, small veins, and replacements in a series of black schists extending as a narrow belt for about 50 miles in a northeast-southwest direction, crossing the boundary line near Blacksburg, S. C., and Kings Mountain, N. C. The deposits near McCormick consist of manganese oxides in association with residual clays derived from micaceous schists.

GEORGIA.

Manganese ores occur in Georgia at three horizons—(1) the ancient crystalline rocks, (2) the Weisner (Cambrian) quartzite, and (3) the Knox (Cambro-Ordovician) dolomite. The following is a general succession of rocks for northwestern Georgia:

[a] Penrose, R. A. F., jr., op. cit., p. 414.
[b] Burchard, E. F., personal communication.

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Succession of rocks in northwestern Georgia.

Cambro-Ordovician: Knox dolomite.
Cambrian:
  Conasauga shale.
  Rome formation.
  Beaver limestone.
  Weisner quartzite.
Pre-Cambrian: Crystalline and metamorphic rocks.

In the crystalline and metamorphic area[a] ores occur at Mount Airy, Habersham County; Bowersville, Hart County; Blue Ridge, Fannin County; and Draketown, Haralson, and Paulding counties. All these deposits are small and none of them have been worked to any extent.

Northeast, east, and southeast of Cartersville, Bartow County, in the area underlain by the Weisner quartzite and Beaver limestone, there are extensive deposits of manganese in residual clays. In late years none of the mines have been operating, and no ore is being produced at present. The larger deposits of the district are the Chumbler Hill and Moccasin mines, east of Whites; the Dobbins mine, the Milner-Harris mine, lot 274, the Mayburn mine (lot 303), and lots 305 and 306, northeast of Cartersville; lots 460 and 465, east of Cartersville; and the Stegall property, near Emerson.

The ore is of four varieties—(1) kidney ore, either amorphous blue psilomelane or a succession of concentric layers of psilomelane and crystalline and granular pyrolusite; (2) irregular masses, either psilomelane or a mixture of psilomelane and pyrolusite; (3) breccia and replacement ore with chert or sandstone fragments; and (4) seams and irregular pockets of soft ore with local hard masses. The clays of the district are yellowish brown or red, according as they are derived from the Weisner quartzite or the Beaver limestone. The ores are generally associated with the yellowish-brown clays, and signs of manganese are present throughout the area covered by them, although only locally are there deposits rich enough to work. The breccia ores occur in residual sandstone or chert masses in the clays.

The Chumbler Hill mine is a large circular open pit in yellow, brown, and variegated clays containing local concentration of kidney ore. The fragments range in size from a few inches to a foot, but, as a rule, are 3 or 4 inches in diameter. They are embedded in yellow and brown sandy clay and are composed of concentric layers of psilomelane and crystalline pyrolusite. The Moccasin mine, a quarter of a mile to the east, contains ore of the same type.

[a] Watson, Thos. L., Preliminary report on the manganese deposits of Georgia: Bull. Geol. Survey Georgia No. 14, 1908, p. 158.

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The Dobbins mine consists of a shaft and several open pits in yellow and brown clay, with local masses of darkly stained manganiferous clay. The main pit contains a large mass of breccia ore, but the principal deposits are seams and pockets of soft blue crystalline ore with local hard masses. These deposits are distributed through sandy clay and range in size from mere seams to masses several feet in extent. The latter generally contain small pockets of sandy clay.

The Milner-Harris mine consists of abandoned shafts and underground workings. The ore on the dumps appears to be of the same type as the Dobbins ore.

Lot 274 and the Mayburn mine are northeast of the Milner-Harris and Dobbins mines. The workings consist mainly of old open pits. The ore occurs in kidneys or in irregular masses, composed of psilomelane, of pyrolusite, or of a mixture of both. The kidneys are embedded in yellow or brown clay; the irregular masses commonly in dark manganiferous clay. Kidneys of beautiful needle ore (pyrolusite) are abundant in the Mayburn mine. Lot 274 contains considerable manganiferous iron ore near the surface.

Lot 460 is about 1 mile east of Cartersville. The ore occurs in porous, irregular ferruginous masses distributed along bands through reddish-brown clay.

Lot 465 is about 1½ miles south of lot 460. The ore here also is ferruginous and very much like that on lot 460. This lot also contains some deposits of breccia ore and kidneys of amorphous blue psilomelane.

These are the best-known deposits, but others of smaller extent occur in surrounding and intervening areas and contain ores similar in form and manner of occurrence to those described.

The areas where manganese ores occur in residual clays of the Knox dolomite are those around Cave Spring and Rome, Floyd County, and at Tunnel Hill, Whitfield County. These clays are generally dark red in color where derived from the Knox dolomite, and of lighter variegated color where residual from the associated shale. In the dark-red clays the ore occurs (1) as cement in residual masses of chert breccia, (2) in porous irregular masses ranging up to a foot in diameter, and (3) as pellet ore. In the lighter-colored clays the ore occurs as (1) cement in sandstone breccia or (2) blue psilomelane kidney ore. The main mines of the Cave Spring district are the Reynolds Mountain, Lowe, Scarborough, and Sanders.

The Reynolds Mountain deposit is about 7 miles north of Cedartown. The workings consist of several pits, most of which have caved in. The ore is dark-blue, partly crystalline pyrolusite, and occurs as cement in large masses of brecciated chert and as irregular porous fragments in the surrounding red clay.

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The Lowe mine, about 2 miles southeast of Cave Spring, consists of a large open pit in dark-red clay. The ore occurs mainly in the form of small pellets, ranging up to one-third of an inch in diameter, with local larger masses of porous ore. Below the red clay is a variegated clay which contains ore associated with large areas of manganiferous clay.

On the Scarborough tract, about 4½ miles southwest of Cave Spring, there are several pits in light-colored variegated clays in which the ore occurs in breccia masses and kidneys of blue psilomelane. In the breccia the fragments form but a subordinate part, the main mass being a mixture of psilomelane and pyrolusite.

The Sanders property is about 2½ miles south of Cave Spring. The workings consist of several pits in variegated clays, in which the ore occurs as soft-ore pockets and small kidneys of hard ore. Both forms commonly occur in manganiferous clay, many of the former containing hard, irregular, partly crystalline masses. The kidneys are commonly only an inch or two in diameter and are composed of psilomelane.

At Tunnel Hill [a] the ore occurs in kidneys, separately and in nests, in dark-red clay. The ore is both massive and crystalline. Irregular masses of manganiferous iron ore are abundant.

Small deposits of little or no commercial importance are found in the vicinity of Rome and Lindale.

ARKANSAS.

Manganese ores of commercial importance have long been known and mined in the Batesville district, in northern Arkansas. Smaller deposits occur in the west-central part of the State, but have not been mined up to the present.

The Batesville district is north of Batesville and east of Cushman, Independence County. The country rock ranges from Cambrian to Carboniferous in age and is in horizontal beds. The following is the general succession of rocks for the district:

General section in manganese region in northern Arkansas.

Mississippian: Boone chert with St. Joe limestone member.
Silurian: St. Clair limestone.
Ordovician:
- Cason shale.
- Polk Bayou limestone.
- Izard limestone.
- St. Peter sandstone.

Manganese ores occur in three different associations in the Batesville district, but all of them are at very nearly the same geologic

[a] Watson, Thos. L., loc. cit.

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horizon, between the Boone chert and the Polk Bayou limestone, or, where that is absent, the Izard limestone.

(1) The Cason shale locally becomes red and sandy and contains an abundance of small lenticular manganiferous iron ore nodules constituting a deposit of low-grade manganiferous iron ore. This bed where exposed is 10 feet or more in thickness. (2) In most of the mines of the district the interval normally occupied by the formations given in the section between the Boone chert and the Polk Bayou limestone is occupied by a manganese-bearing bed of varying nature, which appears to be partly residual material from the erosion of other rocks formerly occurring at this horizon and partly new material derived from deposition. This bed also is called the Cason shale, and although occupying a wider interval is presumably equivalent to (1). It varies in thickness from a few inches to many feet because of the irregular surface of the underlying Polk Bayou limestone. The formation consists in some places of clay with manganese ore fragments, in others of a solid bed of sandy, low-grade ore with associated sediments, and in still others of a partial replacement of sediments. (3) The remaining forms of manganese deposits are associated with residual clays on the slopes of hills below the main manganese bed above mentioned. These deposits consist of masses of psilomelane, pyrolusite, wad, and braunite, and are reconcentrations from the manganese bed above. Only a few deposits have been worked recently, among them the Cason, Reeves, Bales, Roach, and Meeker mines. The principal old mines are the Southern, Polk-Southerd, Turner, Adler, Trent, Baxter, and Montgomery mines.

The Cason, located about 3½ miles north-northeast of Batesville, is the only mine in the district which has worked the nodular manganiferous phases of the Cason shale. This is really a manganiferous iron ore and not a manganese ore, but it is included here on account of its associations. The ore is quarried rather than mined from two large cuts, the bed worked being about 10 feet thick and lying horizontal. It consists largely of red sandy shale with lenticular manganiferous iron pebbles lying in the plane of stratification and averaging between half an inch and 2 inches in larger diameter and from one-fourth to one-third of an inch in thickness. They are very closely spaced, making up more than half of the formation.

The Reeves mine is on Cave Creek, about 6 miles north-northeast of Batesville. The ore occurs in large and small masses scattered through horizontally bedded manganiferous earth. The ore masses are compact or spongy, the former being largely braunite and the latter psilomelane or wad.

The Bales mine is on Cave Creek, about 2 miles northeast of the Reeves mine. The ore occurs in manganiferous earth in irregularities on the surface of the Polk Bayou limestone, on the upper slopes

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of ridges capped by the Boone chert. The ore is mainly of the spongy blue variety. A considerable amount of the underlying limestone has been partly replaced by manganese.

The Meeker mine is on the horizon between the Boone chert and the Polk Bayou limestone, half a mile west of Cushman. The bed here consists of a few feet of sandstone and shale underlain by a ferruginous manganese formation varying in thickness from a few inches to 6 or 8 feet, the irregularity being due to the undulating surface of the underlying limestone. The material is fairly hard and consists of interlaminated manganese and iron oxides with sandy and shaly material, the whole forming a low-grade ore bed. Here and there are pockets of richer ore.

At the Roach mine, about 9 miles north of Batesville, the deposit occurs on a hill which lies in a basin of the St. Peter sandstone. It consists of a mixture of breccia ore, kidney ore, and manganiferous earth replacing clay, and occurs in dark-brown and chocolate clays. The breccia ore forms large masses, many of which are 5 or 6 feet in extent, composed of chert fragments cemented with manganese oxide. The kidney-ore masses average about 3 or 4 inches in diameter and are imbedded in chocolate-colored clays. Many of them contain chert fragments, and, on the other hand, some of the breccia masses have pure nodular psilomelane on the surface. The manganiferous earth occurs in large quantities with the other forms.

The Baxter and Montgomery mines are about half a mile east of the Roach mine. The ore at these mines occurs in red and brown clays on the surface of either the Polk Bayou or the Izard limestone. Dark-red masses, which appear to be decomposed shale and limestone, are seen in the clays. The ore is of two kinds—(1) thin layers of porous blue ore, apparently sedimentary or replacements of sedimentary material, interbedded with red shaly clay containing (2) small lenticular ore nodules similar to those of the Cason mine.

The Adler mine is about three-quarters of a mile north of the Reeves mine. Some of the pits are in the main manganese layer between the Polk Bayou limestone and the Boone chert; others are on the slopes below. The workings are old, and no ore could be seen in them at the time of the writer's visit.

The Trent mine is about 1 mile west of the Reeves mine. The ore is in dark clay on the Polk Bayou limestone, horses of which extend up into the clay. The ore consists of irregular masses of gray crystalline or amorphous braunite and psilomelane.

The Turner mine is about 2¼ miles northeast of Cushman. The ore is spongy blue psilomelane and gray crystalline braunite in irregular masses scattered through reddish-brown clays on the surface of the Izard limestone. The Polk Bayou limestone appears to be absent, but the Boone chert is present locally above the clay.

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The Polk-Southerd mine is about half a mile southwest of the Turner, but the pits are old and nothing could be seen except that the Boone chert formed the upper part of the walls.

The Southern mine is about 1 mile northeast of Cushman. It consists of a number of old open pits and shafts. The latter go through the Boone chert into the underlying manganese-bearing layer. The rock underlying this layer is the Polk Bayou limestone, as shown in the Grubb cut, a little to the northeast. In the pits ocherous and manganiferous clay is exposed under the Boone chert. This clay contains manganese ore masses here and there.

The deposits of west-central Arkansas are associated with brown-iron ore deposits. They lie on a novaculite bed of Silurian or Devonian age, immediately underneath a heavy Carboniferous shale series. Neither the iron nor the manganese deposits are of sufficient size to be considered of importance commercially.

UTAH.

Several deposits of manganese are known in Utah and others are being discovered. The best-known deposits are in Grand County, about 10 miles south of Little Grande, a station on the Rio Grande Western Railway. The ore here occurs as a replacement of calcareous layers along a certain horizon in the Triassic sandstone series. Above this horizon are beds of white and gray quartzite; below it are red thin-bedded limestones and calcareous sandstones grading downward into the massive red sandstone (presumably the Vermilion Cliff sandstone). The ore, consisting of blue granular and crystalline pyrolusite, is found abundantly as float and as replacements of layers and in pockets in the bed rock near the surface, where the overlying rocks have been eroded.

NEVADA.

A small deposit of manganese ore occurs 2 miles east of Golconda, Nev. It is bedded and varies in thickness from a few inches to 3 feet and is interstratified with calcareous and siliceous tufa. There is good evidence that this is a hot-spring deposit in a small basin in the tufa, as supposed vents of the springs are seen on the slopes of the hills above it. The ore is mainly wad in black powder or small fragments, slightly consolidated.

CALIFORNIA.

Manganese ore occurs in California in two different associations. (1) Near Meadow Valley, in Plumas County, and at other localities in the Sierra Nevada pyrolusite and psilomelane occur in veins in the Calaveras formation; (2) near the coast, north and south of San

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Francisco, ore occurs as local small, thin lenses interbedded with jaspers of the Franciscan formation. Deposits of the first class have not figured as active producers up to the present time and in general are too small to be considered of importance. The principal deposits belonging to the second class so far found are located southeast of Livermore in Alameda and Santa Clara counties. Among these deposits are the old Ladd, the Fable, Pennsylvania, and Isler Mountain mines and the Overacker property. The ore is supposed to be largely in the form of manganite[a] and an impure oxide.

In the Ladd mine the ore occurs in what appears to be a fault fissure, having a general direction of N. 80° W. and dipping very steeply to the south. The fissure averages about 4 or 5 feet in width, with a hanging wall of massive pink jasper and a foot wall of thin-bedded gray jasper and clay. It has been mined to a considerable depth in open cuts along the strike. The ore occurs as cavity fillings, as infiltration and replacement deposits in red and yellow clays in the fissure, and as veins and breccia cement in the massive south wall. It is black in color and hard or soft according as it is associated with clays or with the jasper wall.

Along the strike of this fissure about half a mile to the west is a more recent opening consisting of an incline and stopes. The associations here are the same as at the Ladd mine.

The other deposits of the Livermore district are of a different nature. They consist of small lenses ranging up to 100 or more feet in length, and from a few inches to 5 feet or more in thickness. These lenses appear to be interbedded with the jasper layers and consist of black porous ore with seams of quartz. Along the edges there is considerable replacement of chert by manganese oxide.

Manganese indications are found throughout the Franciscan jasper areas of west-central California, and small deposits occur locally. Among them are those of Red Rock Island and Sausalito, near San Francisco, those of the Russian River valley, and a few deposits east of Tres Pinos, San Benito County, and near San Luis Obispo, San Luis Obispo County. So far, however, these deposits have not been found to be of commercial importance.

OTHER STATES.

Small quantities of manganese ore occur in Massachusetts, Connecticut, New York, and Pennsylvania in association with brown iron ore. The deposits are of the same nature as those of Vermont and Virginia. Locally there are veins of rhodonite in the New England crystalline area. Franklinite, willemite, and zincite, with some tephroite and rhodonite, occur near Franklin Furnace and Ogdensburg,

[a] Penrose, R. A. F., jr., op. cit. p. 481.

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N. J., in crystalline limestone associated with gneiss. All these minerals contain some manganese, but the ores are used largely in the manufacture of zinc oxide and spelter. The residuum left after the volatilization and oxidation of the zinc, however, from those ores which are richest in manganese, is used in blast furnaces for the manufacture of spiegeleisen. In Alabama manganese ores are found at several horizons. They are continuations of the Georgia deposits, but are of much smaller extent. In Custer County, S. Dak., wad occurs in fissures and beds in Carboniferous limestone in association with cave deposits. The central Texas crystalline area locally contains veins of manganiferous garnet and tephroite, which are, however, of no commercial value.

MANGANIFEROUS IRON ORES.

APPALACHIAN VALLEY.

The manganiferous iron ores of the Appalachian Valley include deposits or parts of deposits of brown iron ore rich in manganese and manganese deposits rich in iron, in the States of Vermont, Massachusetts, Connecticut, New York, Pennsylvania, Virginia, Tennessee, North Carolina, Georgia, and Alabama. The most important are those in Vermont, Virginia, and Tennessee, which have been mentioned in the descriptions of manganese deposits. These ores vary from a coarse, easily separated mixture of manganese and iron oxides to a mixture indistinguishable to the eye. The principal minerals are limonite and psilomelane, but pyrolusite is of common occurrence.

ARKANSAS.

The manganiferous iron ores of Arkansas occur in the manganese horizons in the Batesville and west-central Arkansas districts and are described with the manganese deposits of that State.

LAKE SUPERIOR DISTRICT.

Much of the ore of the Lake Superior district contains between 1 and 10 per cent of metallic manganese. It is in the form of oxide, largely pyrolusite, occurring locally as small patches intimately mixed with red hematite.

Most of the manganiferous iron ores of the district have come from the Gogebic, Menominee, Mesabi, and Marquette ranges. At present, however, numerous deposits of manganiferous iron ore are being discovered on the Cuyuna Range of central Minnesota, where it occurs as local bodies in iron-ore deposits. A few deposits have also been found in the Baraboo Range in southern Wisconsin. Bog ores consisting of limonite and wad occur locally in northern Wisconsin.

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COLORADO.

Manganiferous iron ores are found in the Cebolla district in Gunnison County, Colo. Manganese oxide is here associated with limonite in clay, a surface alteration of an iron carbonate in localities adjacent to a trachyte capping.[a]

UTAH.

A deposit of manganiferous iron ore has recently been discovered in western Utah near Joy, Juab County. It is said to occur along the contact of a limestone and granite, the latter being on the foot wall. There has been no production from this area because of lack of railroad facilities.

OTHER STATES.

Low-grade manganiferous iron ore occurs in both the hematite and the brown-ore deposits of Missouri. The hematite deposits that have manganese associated with them are chiefly those occurring in the porphyry. Bog deposits of limonite and wad occur at Wickes, Jefferson County, Mont.

MANGANIFEROUS SILVER ORES.

COLORADO.

Manganiferous silver ores occur at Leadville, Colo., in large deposits at or near the contact of porphyry and blue limestone, replacing the latter. These deposits consist of a black mixture of manganese and iron oxides with lead carbonate and silver. The manganese content varies from 10 to 40 per cent, being high where the iron is low and conversely. Manganese and iron oxides are associated only with the oxidized portions of the Leadville deposits. In the lower unoxidized portions the minerals are mainly pyrite, sphalerite, and galena. Manganese minerals are conspicuously absent and it is believed that the large quantity of manganese oxide in the oxidized ore is due to infiltration from the porphyry.[b] The ore is used both in the steel industry and for fluxing.

MONTANA.

Manganiferous silver ores occur in veins in the Butte granite at Butte, Mont. These veins traverse the area north, west, and south of Butte, nearly surrounding the copper area, in which little or no silver ore occurs. The outcrops and upper portions of the silver

[a] Leith, C. K., Iron ores of the West: Bull. U. S. Geol. Survey No. 285, 1906, p. 17.

[b] Emmons, S. F., and Irving, J. D., Downtown district of Leadville, Colo.: Bull. U. S. Geol. Survey No. 320, 1907, p. 34.

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veins are black, and consist of a mixture of quartz and manganese oxides, mainly wad carrying silver. At greater depths the veins are white and pink and consist of silver and lead sulphides, with some pyrite, chalcopyrite, and locally sphalerite, in a gangue of quartz, rhodonite, and some rhodochrosite. In the Black Rock mine, where the veins are typically developed, the change takes place at a depth between 150 and 300 feet. The veins vary in width up to 100 feet or more, a large part of them generally being made up of included lenses of granite. The veins are branching and anastomosing, but all have a general east-west direction, ranging between northeast-southwest and southeast-northwest.

The manganese ores of Butte have been of little value commercially. In a few places the oxidized ore has been mined in former years, mainly for its manganese content for use as flux in smelting; but as a rule the ore is mined for its silver.

Manganiferous silver ores similar to the Leadville ore occur at Neihart, Cascade County, and Castle, Meagher County. The ores are in the form of brown and black oxides and occur in the upper portions of veins which grade down into unaltered sulphide ores of silver.

NEW MEXICO.

Manganiferous and ferruginous silver ores occur in southwestern New Mexico at Kingston and Lake Valley, Sierra County.

ARIZONA.

Manganese ores are abundantly developed in the oxidized portions of the metalliferous deposits at Tombstone, Cochise County, Ariz. The deposits are in the form of veins or chimneys, the manganese occurring as pyrolusite and earthy black wad, with some psilomelane in the upper portions, in a calcareous and siliceous gangue.

UTAH.

Manganiferous silver ores occur near Modena, Iron County, and in the Tintic district, Utah. The ores of the Tintic district are used for flux in the local smelters. The ore at Modena consists of a mixture of iron and manganese oxides, the latter largely wad, and occurs in the decomposed limestone on the foot wall of an igneous dike.

NEVADA.

Manganiferous and ferruginous silver ores are found at Pioche, Lincoln County, and at Eureka County, Nev.

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USES OF MANGANESE.

The uses of manganese in the industries may be classified as follows: (1) Metallurgical, in the manufacture of alloys and in copper and silver reduction; (2) chemical, as an oxidizer and as a coloring material.

The manganese ores used in the manufacture of alloys are dependent in value on the percentage of metallic manganese present and on the absence of injurious substances like phosphorus and sulphur. The latter condition is especially important in the manufacture of the alloys with iron. Spiegeleisen, ferromanganese, silicomanganese, and silicospiegel are alloys of iron and manganese. Spiegeleisen contains below 20 per cent of manganese; ferromanganese has a manganese content ranging from 20 to 90 per cent, above which the alloy becomes unstable. Silicon and carbon are present in varying quantities. Silicomanganese and silicospiegel contain a large percentage of silicon. Spiegeleisen and ferromanganese are used in the manufacture of steel in the following ways: (*a*) As reducers of iron oxide in the final melting, the manganese oxide formed going into slag; (*b*) as recarburizers of steel, in which their carbon content is utilized; (*c*) for counteracting the effects of phosphorus and sulphur by the formation of manganese compounds with these elements; (*d*) in the manufacture of manganese steel, used for railroad and street-car rails on curves, burglar-proof safes, car wheels, ore crushers, dipper teeth for steam shovels, cover plates for lifting magnets, agricultural implements, such as plow and cultivator points, railway-car couplers, dredger pins, and many other appliances in which hardness and toughness are special requisites. The addition of small quantities of manganese gives to steel hardness, ductility, and strength.

Manganese is also used to form alloys with copper, zinc, aluminum, tin, lead, magnesium, and silicon, and with combinations of these elements. Manganese bronze is used for steamboat propellers and other alloys are used for coins, statuary, and ornamental purposes. Certain alloys of manganese, aluminum, and copper, known as Heusler's alloys, have come into prominence recently on account of their magnetic properties, and extensive experiments are being made with them.

Manganese oxides are used to a slight extent in copper and silver reduction as a substitute for iron oxides.

Manganese oxide is used as an oxidizer in the manufacture of chlorine, bromine, and oxygen and of disinfectants like potassium permanganate; as a drier in paints and varnishes; as a decolorizer of glass; and in the manufacture of the Leclanche battery and of dry

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cells. In these uses the value of the ore depends on its available oxygen content—that is, on its percentage of pyrolusite or manganese peroxide. A considerable tonnage of manganese oxide is used yearly in the manufacture of dry cells.[a]

As a coloring material manganese is used in calico dyeing; for coloring bricks, glass, and pottery; and in the manufacture of green and violet paints.

Compounds of manganese are used in a small way for medicine, and the mineral rhodonite, a silicate of manganese, is used rarely for ornamental purposes on account of its beautiful pink color.

THE MANGANESE INDUSTRY IN THE UNITED STATES.

The quantity of manganese ore mined in the United States is at present, as for several years past, very small. Of the important manganese districts—the Blue Ridge and James River valley districts in Virginia, the Cartersville and Cave Spring districts in Georgia, and the Batesville district in Arkansas—only the first two produced manganese ore in 1907. Of a total of 5,604 tons mined, 4,604 tons was produced in Virginia, 800 tons in South Carolina, and 100 tons each in Tennessee and California. About one-sixth of the above production was used in the manufacture of spiegeleisen and ferromanganese, the rest being consumed in the brick, pottery, and chemical industries.

Virginia has always been the principal manganese producer, with Georgia and Arkansas as second and third, respectively. Of the total production of 396,623 tons of manganese ore in the United States, these three States furnished about 95 per cent, Virginia alone furnishing more than 55 per cent.

The manganese ores of the United States generally occur in small discontinuous pockets, few of which contain more than 25,000 tons and most of them much less. A large proportion of the ore is of low grade, containing considerable iron, silica, and phosphorus. The eastern ores are embedded in clay and must be washed and sorted before they are fit for the market. The small extent of the deposits discourages the erection of expensive concentrating plants; hence mining is carried on only on a small scale.

The quantity of manganiferous silver ore produced in 1907 was very much larger than that of manganese ore, 67,514 tons being mined in the Leadville region for use in the manufacture of iron-manganese alloys and 40,000 tons or more being mined at Leadville and other localities in the West for use as flux in the silver and copper smelters. A large quantity of the iron ores produced also contained

[a] Burgess, C. F., personal communication.

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an appreciable quantity of manganese, but not sufficient to make them of use in the manganese industry.

By far the larger part of the manganese ores consumed in the United States is imported from foreign countries, chiefly from India, Brazil, Cuba, and the East Indies. In 1907 the imports amounted to 209,032 tons, as compared with which the 5,604 tons produced in the United States may be regarded as insignificant. Most of the imported ore is used in the steel industry. A small percentage is used for chemical purposes, chiefly in the manufacture of dry cells and for coloring bricks and pottery.

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SURVEY PUBLICATIONS ON IRON AND MANGANESE ORES.

A number of the principal papers on iron and manganese ores published by the United States Geological Survey or by members of its staff are listed below. The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.; the monographs from either that official or the Director of the Survey. In addition to these papers, several geologic folios contain descriptions of iron-ore deposits of more or less importance.

BALL, S. H. The Hartville iron ore range, Wyoming. In Bulletin No. 315, pp. 190–205. 1907.

——— Titaniferous iron ores of Iron Mountain, Wyoming. In Bulletin No. 315, pp. 206–212. 1907.

BARNES, P. The present technical condition of the steel industry of the United States. Bulletin No. 25. 85 pp. 1885. Exhausted.

BAYLEY, W. S. The Menominee iron-bearing district of Michigan. Monograph XLVI. 513 pp. 1904. $1.75.

——— (See also Clements, J. M. Smyth, H. L., Bayley, W. S., and Van Hise, C. R.; also Van Hise, C. R., Bayley, W. S., and Smyth, H. L.)

BIRKINBINE, J. The production of iron ores in various parts of the world. In Sixteenth Ann. Rept., pt. 3, pp. 21–218. 1894.

BOUTWELL, J. M. Iron ores in the Uinta Mountains, Utah. In Bulletin No. 225, pp. 221–228. 1904. 35c.

BURCHARD, E. F. The iron ores of the Brookwood district, Alabama. In Bulletin No. 260, pp. 321–334. 1905. 40c.

——— The Clinton or red ores of the Birmingham district. In Bulletin No. 315, pp. 130–151. 1907.

——— The brown ores of the Russellville district, Alabama. In Bulletin No. 315, pp. 152–160. 1907.

——— The Clinton iron ore deposits in Alabama. In Trans. Am. Inst. Min. Eng., vol. 39, 1908, pp. 997–1055.

——— An estimate of the tonnage of available Clinton iron ore in the Birmingham district, Alabama. In Bulletin No. 340, pp. 308–317. 1908.

BURCHARD, E. F., BUTTS, CHARLES, and ECKEL, E. C. Iron ores, fuels and fluxes of the Birmingham district, Alabama. (In preparation.)

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BUTTS, CHARLES. (See Burchard, E. F., Butts, Charles, and Eckel, E. C.)

CLEMENTS, J. M. The Vermilion iron-bearing district of Minnesota. Monograph XLV. 463 pp. 1903. $3.50.

CLEMENTS, J. M., SMYTH, H. L., BAYLEY, W. S., and VAN HISE, C. R. The Crystal Falls iron-bearing district of Michigan. Nineteenth Ann. Rept., pt. 3, pp. 1–157. 1898.

——— The Crystal Falls iron-bearing district of Michigan. Monograph XXXVI. 512 pp. 1899. $2.

DILLER, J. S. Iron ores of the Redding quadrangle, California. In Bulletin No. 213, pp. 219–220. 1903. 25c.

——— So-called iron ore near Portland, Oreg. In Bulletin No. 260, pp. 343–347. 1905. 40c.

ECKEL, E. C. Utilization of iron and steel slags. In Bulletin No. 213, pp. 221–231. 1903. 25c.

——— Iron ores of the United States. In Bulletin No. 260, pp. 317–320. 1905. 40c.

——— Limonite deposits of eastern New York and western New England. In Bulletin No. 260, pp. 335–342. 1905. 40c.

——— Iron ores of northeastern Texas. In Bulletin No. 260, pp. 348–354. 1905. 40c.

——— The Clinton hematite. In Eng. and Min. Jour., vol. 79, pp. 897–898. 1905.

——— The iron industry of Texas, present and prospective. In Iron Age, vol. 76, pp. 478–479. 1905.

——— The Clinton or red ores of northern Alabama. In Bulletin No. 285, pp. 172–179. 1906.

——— The Oriskany and Clinton iron ores of Virginia. In Bulletin No. 285, pp. 183–189. 1906.

——— Iron ores, pig iron, and steel. In Mineral Resources U. S. for 1907, pt. 1, pp. 51–85. 1908.

——— (See also Hayes, C. W., and Eckel, E. C.; also Burchard, E. F., Butts, Chas., and Eckel, E. C.)

HARDER, E. C. Manganese deposits of the United States; with sections on foreign deposits, chemistry, and uses. (In preparation.)

——— Manganese ores. In Mineral Resources U. S. for 1907, pt. 1, pp. 87–110. 1908.

——— (See also Leith, C. K., and Harder, E. C.)

HAYES, C. W. Geological relations of the iron ores in the Cartersville district, Georgia. In Trans. Am. Inst. Min. Eng., vol. 30, pp. 403–419. 1901.

——— Manganese ores of the Cartersville district, Georgia. In Bulletin No. 213, p. 232. 1903. 25c.

HAYES, C. W., and ECKEL, E. C. Iron ores of the Cartersville district, Georgia. In Bulletin No. 213, pp. 233–242. 1903. 25c.

HOLDEN, R. J. The brown ores of the New River-Cripple Creek district, Virginia. In Bulletin No. 285, pp. 190–193. 1906.

IRVING, J. D., and VAN HISE, C. R. The Penokee iron-bearing series of Michigan and Wisconsin. In Tenth Ann. Rept., pt. 1, pp. 341–507. 1889. $2.35.

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IRVING, J. D., and VAN HISE, C. R. The Penokee iron-bearing series of Michigan and Wisconsin. Monograph XIX. 534 pp. 1892. $1.70.

KEITH, A. Iron-ore deposits of the Cranberry district, North Carolina-Tennessee. In Bulletin No. 213, pp. 243–246. 1903. 25c.

KEMP, J. F. The titaniferous iron ores of the Adirondacks [N. Y.]. In Nineteenth Ann. Rept., pt. 3, pp. 377–422. 1899.

KINDLE, E. M. The iron ores of Bath County, Ky. In Bulletin No. 285, pp. 180–182. 1906.

LEITH, C. K. The Mesabi iron-bearing district of Minnesota. Monograph XLIII. 316 pp. 1903. $1.50.

——— Geologic work in the Lake Superior iron district during 1902. In Bulletin No. 213, pp. 247–250. 1903. 25c.

——— The Lake Superior mining region during 1903. In Bulletin No. 225, pp. 215–220. 1904. 35c.

——— Iron ores in southern Utah. In Bulletin No. 225, pp. 229–237. 1904. 35c.

——— Genesis of the Lake Superior iron ores. In Economic Geology, vol. 1, pp. 47–66. 1905.

——— Iron ores of the western United States and British Columbia. In Bulletin No. 285, pp. 194–200. 1906.

——— The geology of the Cuyuna iron range, Minnesota. In Economic Geology, vol. 2, pp. 145–152. 1907.

——— Iron ore reserves. In Economic Geology, vol. 1, pp. 360–368. 1906.

——— A summary of Lake Superior geology with special reference to recent studies of the iron-bearing series. In Trans. Am. Inst. Min. Eng., vol. 35, pp. 454–507. 1904.

LEITH, C. K., and HARDER, E. C. The iron ores of the Iron Springs district, southern Utah. Bulletin No. 338. 102 pp. 1908.

PHALEN, W. C. Iron ores near Ellijay, Ga. In Bulletin No. 340, pp. 330–334. 1908.

SMITH, GEO. O., and WILLIS, B. The Clealum iron ores, Washington. In Trans. Am. Inst. Min. Eng., vol. 30, pp. 356–366. 1901.

SMITH, P. S. The gray iron ores of Talladega County, Alabama. In Bulletin No. 315, pp. 161–184. 1907.

SMYTH, H. L. (See Clements, J. M., Smyth, H. L., Bayley, W. S., and Van Hise, C. R.; also Van Hise, C. R., Bayley, W. S., and Smyth, H. L.)

SPENCER, A. C. The iron ores of Santiago, Cuba. In Eng. and Min. Jour., vol. 72, pp. 633–634. 1901.

——— Manganese deposits of Santiago, Cuba. In Bulletin No. 213, pp. 251–255. 1903. 25c.

——— Magnetite deposits of the Cornwall type in Berks and Lebanon counties, Pennsylvania. In Bulletin No. 315, pp. 185–189. 1907.

——— Three deposits of iron ore in Cuba. In Bulletin No. 340, pp. 318–329. 1908.

——— Magnetite deposits of the Cornwall type in Pennsylvania. Bulletin No. 359. 102 pp. 1908.

SWANK, J. M. Iron and steel and allied industries in all countries. In Eighteenth Ann. Rept. pt. 5, pp. 51–140. 1896.

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VAN HISE, C. R. The iron-ore deposits of the Lake Superior region. In Twenty-first Ann. Rept. pt. 3, pp. 305–434. 1901.

——— (See also Clements, J. M., Smyth, H. L., Bayley, W. S., and Van Hise, C. R.; also Irving, J. D., and Van Hise, C. R.)

VAN HISE, C. R., BAYLEY, W. S., and SMYTH, H. L. Preliminary report on the Marquette iron-bearing district of Michigan. In Fifteenth Ann. Rept. pp. 477–650. 1894.

——— The Marquette iron-bearing district of Michigan, with atlas. Monograph XXVIII. 608 pp. 1897. $5.75.

WEEKS, J. D. Manganese. Sixteenth Ann. Rept., pt. 3, pp. 389–457. 1895.

WILLIS, B. (See Smith, G. O., and Willis, B.)

WOLFF, J. E. Zinc and manganese deposits of Franklin Furnace, N. J. In Bulletin No. 213, pp. 214–217. 1903. 25c.

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ALUMINUM ORES.

SURVEY PUBLICATIONS ON ALUMINUM ORES—BAUXITE, CRYOLITE ETC.

The following reports published by the Survey or by members of its staff contain data on the occurrence of aluminum ores and on the metallurgy and uses of aluminum. The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.; the folios from either that official or the Director of the Survey.

BURCHARD, E. F. Bauxite and aluminum. In Mineral Resources U. S. for 1906, pp. 501–510. 1907. 50c.

CANBY, H. S. The cryolite of Greenland. In Nineteenth Ann. Rept., pt. 6, pp. 615–617. 1898.

HAYES, C. W. Bauxite. In Mineral Resources U. S. for 1893, pp. 159–167. 1894. 50c.

——— The geological relations of the southern Appalachian bauxite deposits. In Trans. Am. Inst. Min. Eng., vol. 24, pp. 243–254. 1895.

——— Bauxite. In Sixteenth Ann. Rept., pt. 3, pp. 547–597. 1895.

——— The Arkansas bauxite deposits. In Twenty-first Ann. Rept., pt. 3, pp. 435–472. 1901.

——— Bauxite in Rome quadrangle, Georgia–Alabama. Geologic Atlas U. S. folio No. 78, U. S. Geol. Survey, 1902, p. 6. 25c.

——— The Gila River alum deposits. In Bulletin No. 315, pp. 215–223. 1907.

HUNT, A. E. In Mineral Resources U. S. for 1892, pp. 227–254. 1893. 50c.

PACKARD, R. L. Aluminum and bauxite. In Mineral Resources U. S. for 1891, pp. 147–163. 1892. 50c.

——— Aluminum. In Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 539–546. 1895.

PHALEN, W. C. Bauxite and aluminum. In Mineral Resources U. S. for 1907, pt. 1, pp. 693–705. 1908.

SCHNATTERBECK, C. C. Aluminum and bauxite [in 1904]. In Mineral Resources U. S. for 1904, pp. 285–294. 1905.

SPURR, J. E. Alum deposits near Silver Peak, Esmeralda County, Nev. In Bulletin No. 225, pp. 501–502. 1904. 35c.

STRUTHERS, J. Aluminum and bauxite [in 1903]. In Mineral Resources U. S. for 1903, pp. 265–280. 1904. 70c.

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ASPHALT.

AN OCCURRENCE OF ASPHALTITE IN NORTHEASTERN NEVADA.

By ROBERT ANDERSON.

INTRODUCTION.

In November, 1908, the writer visited an asphaltite prospect that has been opened in Eureka County, northeastern Nevada, about 15 miles south of Palisade. It is situated in the Pinon Range, up a canyon about 4 miles east of the Maples ranch, which is in the valley of Pine Creek on the Eureka and Palisade Railway. The occurrence of asphaltite here is interesting from the fact that heretofore no asphaltic substance has been recorded from that State.

THE ASPHALTITE.

CHARACTER.

The asphaltite found here would be commercially known as "grahamite," but its characteristics show it to differ from the variety so known scientifically. A few tests revealed a close relationship to the variety from Indian Territory described by G. H. Eldridge[a] as impsonite. It has a bright pitchlike luster on fresh surfaces, a jet-black color, a crushed or somewhat layered structure, and irregular or very imperfectly conchoidal fracture. It is very brittle, but when pure is compact and homogeneous. Its powder is black, and it leaves a light-black streak with a faint brownish tinge. At first sight a fragment of it might be mistaken for a piece of hard coal, but its light weight reveals a marked distinction at once, the specific gravity being roughly estimated at somewhat less than 2. When held in a flame it decrepitates slightly at first, softens and swells up in incip-

[a] The asphalt and bituminous rock deposits of the United States: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 1, 1901, pp. 265 et seq.

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ient fusion, and burns, continuing to burn a short time after removal from the flame, and then forms a light coke. In boiling water it is not affected, but it softens and cokes when heated in a close tube. It is insoluble in turpentine. These qualities show it to be different from albertite and to be most like impsonite.

OCCURRENCE.

The asphaltite occurs as a filling in fractures within steeply dipping Carboniferous strata. These rocks consist of alternating sharply defined beds of sandy shale, calcareous shale, and sandstone, mostly well indurated, with important zones of hard, coarse conglomerate. They strike in general S. 75° E. and dip 50° to 60° on the average, though in places in this region they have been thrown into a nearly vertical position. They are referred to the Carboniferous on the basis of specimens of *Productus* found in beds supposedly of the same series a little over 2 miles east-southeast from the Maples ranch house. An indeterminate plant impression was found in the sandstone at the asphaltite prospect.

The asphaltite deposits can not be traced at the surface, but the prospect openings from which several tons of the material have been taken afford exposures for a short way. The principal deposit follows a zone of fracturing in the sandstone and shale beds. This vein has been traced about 100 yards beyond the main opening by small pits excavated at the surface, and appears to strike about N. 60° E. and to stand nearly vertical. The asphaltite occurs in lenses, stringers, and sheets along a fractured zone about a yard wide, mingled with and impregnating the fissured rock. Every gradation may be seen, from the pure material which occurs in wedge-shaped masses to sand and clay impregnated and cemented by the asphaltite. The thickest lens of the solid pure material exposed in the cuttings is about 18 inches thick. Though asphaltic material is continuous along the vein, the filling is irregular. It looks as if it had been intruded as a liquid into every crevice of a splintery fracture and had there hardened.

The country rock on either side of the vein is impregnated for a little way, especially along bedding planes. At the prospect an opening has been made at a distance of 40 feet along the strike of the beds from the main vein, exposing a zone about 4 feet thick of softer, somewhat clayey, and crushed beds between hard strata of shale. This zone is impregnated with the asphaltite and contains fairly regular layers of it several inches thick following the bedding.

It is probable that the asphaltite of this region has wide extent. Stringers of it are reported to have been found about half a mile up the canyon in a general easterly direction from the prospect, possibly

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along the extension of the zone already described; on Trout Creek about 3 miles to the north; and on Willow Creek about 7 miles to the south.

CONCLUSIONS AS TO THE POSSIBLE OCCURRENCE OF OIL.

There is little doubt that the strata in this region at one time contained considerable petroleum. Owing, however, to the disturbed condition of the beds, their great age, the long lapse of time since the disturbances took place, and the consequent opportunities for the escape of the petroleum content, it is likely that almost if not quite all of such oil has escaped or become altered in the derived form of asphalt. Further investigation should be made before such a conclusion should be considered as applying to any area except the immediate vicinity of the asphalt prospect mentioned. Strata of probable Paleozoic age elsewhere in this portion of Nevada are reported to be petroliferous, and it is not impossible that careful study might reveal areas in which the conditions are more favorable than in the one here discussed.

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GRAHAMITE DEPOSITS OF SOUTHEASTERN OKLAHOMA.

By JOSEPH A. TAFF.

LOCATION AND OCCURRENCE.

The grahamite deposits of Oklahoma occur in two distinct geologic and structural provinces, the Ouachita Mountains, in the southeastern part of the State, where the mineral has been found at a number of localities, and the plains region, between the Arbuckle and Wichita mountains, where it occurs in a single district. (See fig. 23.) In the Ouachita region the grahamite occurs in greatly folded rocks, but the rocks that contain similar deposits in the plains lie almost flat.

The grahamite is found filling fissures in the form of veins or dikes that cut across or extend with the bedding of the rocks. In the Ouachita Mountains it occurs in both Ordovician and Carboniferous rocks; in the plains region it is found in late Carboniferous or probably "Permo-Carboniferous" strata.

During the geologic surveys of the Ouachita region of Indian Territory, now southeastern Oklahoma, in 1897, grahamite veins were discovered in McGee Valley, T. 1 N., R. 14 E. More extensive deposits were located later the same season in Impson Valley on Tenmile Creek, T. 1 S., R. 15 E. The veins in Impson Valley had been considered beds of coal for a number of years, and the lands including them were taken up under coal leases. Little had been done in the way of development, however, beyond prospecting on one of the thicker veins. A deposit of bitumen nearly related to grahamite was located on the south slope of Black Fork Mountain, about 3 miles east of Page, on the Kansas City Southern Railway. This deposit occurs as a vein similar to those in Impson Valley. In 1906 grahamite deposits were noted at certain prospects in McGee Creek valley, T. 1 S., R. 14 E., where a small amount of development work had been done. Recently a deposit of grahamite in a vein of considerable thickness has been located in Jackfork Valley, about 10 miles west of Tuskahoma, where active development is now

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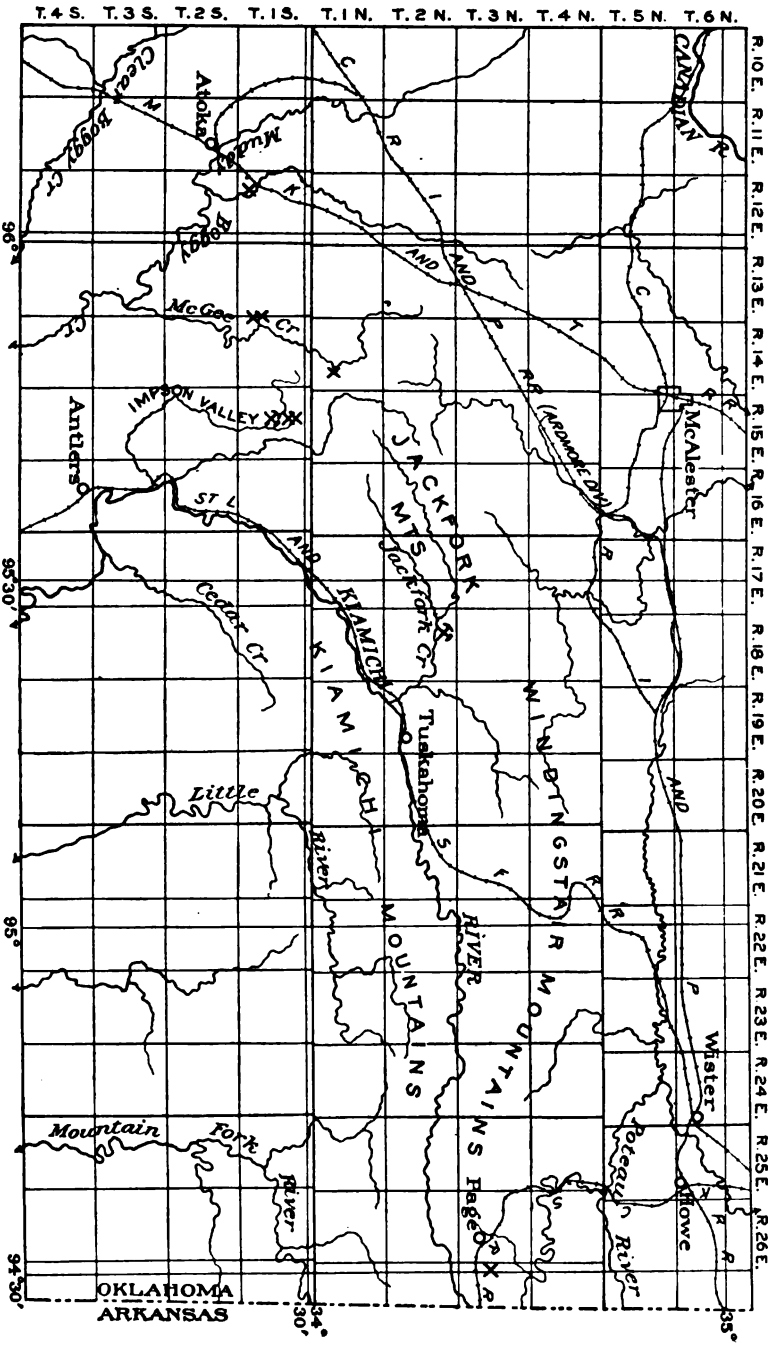

FIGURE 23.—Map of southeastern Oklahoma, showing location of grahamite deposits.

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going on. The deposits thus far named occur in rocks of Carboniferous age. In 1906 or 1907 a vein of grahamite was discovered in Ordovician rocks on Boggy Creek, about 6 miles northeast of Atoka, T. 1 S., R. 12 E. Grahamite or a nearly related bitumen was discovered in 1902 about 6 miles northwest of Loco, or 12 miles east-northeast of Duncan. This deposit is in the rolling plain between the Arbuckle and Wichita mountains, and occurs in undisturbed late Carboniferous rocks.

PHYSICAL FEATURES OF THE REGION.

The Ouachita Mountain region, in which the grahamite deposits occur, consists of groups or ranges of rugged sandstone hills and mountains. These groups of mountains are separated from one another by wide and almost flat valleys. The principal mountain groups are as follows: (1) Winding Stair Mountain, which, in its easterly extension, near the Oklahoma-Arkansas line, is known as Rich Mountain. A high member of the same mountain group a little north of Rich Mountain and separated from it by a narrow valley is known as Black Fork Mountain. (2) Kiamichi Mountain, which extends from the Arkansas line westward, south of Kiamichi River. (3) The Jackfork Mountains, composed of a couple of high, rugged ridges about 15 miles in length that lie near the sources of Jackfork Creek and between the west ends of Winding Stair and Kiamichi mountains. Winding Stair Mountain is succeeded on the north and Kiamichi Mountain on the south by successively lower ridges of a similar kind until the Arkansas and Canadian valleys are reached on the north and that of Red River on the south. The high ridges composing these mountains in Oklahoma rise gradually from elevations of about 1,000 feet above sea near the Missouri, Kansas and Texas Railway on the west to about 2,900 feet near the state line on the east. Kiamichi River flows southwestward and southward from Tuskahoma in a deep gorge or boxlike canyon through Kiamichi Mountain. There is no gap or pass in this mountain farther east, but to the west it is cut by the deep, narrow gorges of Buck and McGee creeks. Winding Stair Mountain has a single high gap where the St. Louis and San Francisco Railroad crosses it, and a similar depression southwest of Page separates Winding Stair Mountain from Rich Mountain.

A broad, flat valley lies between Winding Stair and Kiamichi mountains. In the region of Talihina, 10 miles northeast of Tuskahoma, it is broken by a group of chert and novaculite hills known locally as the Potato Hills. The south ridge of the Jackfork group of mountains stands in the course of this broad valley and separates it into two parts that are occupied by the south and north forks of Jackfork Creek. This valley affords a means of easy access to the region, ex-

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tending through the Ouachita Mountains from the source of Kiamichi River at the Arkansas-Oklahoma state line westward to Atoka.

All the grahamite deposits except that on Black Fork Mountain, near Page, are contiguous to or in the main valley leading through the central part of the mountain region. The Impson Valley deposits in T. 1 S., R. 15 E., are more accessible to the lower Kiamichi Valley, and shipments of grahamite from these deposits are made from Kosoma, on the St. Louis and San Francisco Railroad, about 8 miles north of Antlers. Grahamite from the mines in Jackfork Valley, T. 2 N., R. 18 E., is hauled to Tuskahoma and there shipped by rail. The deposits in McGee Creek valley are more accessible to the Missouri, Kansas and Texas Railway at Stringtown or Atoka, from which flat valleys extend to the mines.

STRATIGRAPHY OF ROCKS CONTAINING GRAHAMITE.

The rocks of the region in which the grahamite deposits are found consist of three general classes—shales, sandstones, and cherts or cherty novaculite. There are various gradations from one to the other of these classes of rock. The section of the formations in the Ouachita Mountains, in descending order, is as follows:

CARBONIFEROUS ROCKS.

1. Atoka formation, 3,000 to 6,000 feet thick; composed of numerous beds of sandstone and shale. The sandstone is most abundant in the middle and lower parts. In the central part of Winding Stair Mountain the sandstones in this formation attain a thickness of several thousand feet. Exact measurements of the thickness can not be obtained because of the excessive disturbances to which the rocks have been subjected.

2. Caney shale, 800± feet thick; composed of black and blue shales with bowlders of limestone, chert, quartzite, etc.

3. Jackfork sandstone, 5,000 feet thick; composed of thick beds of gray and brown sandstone with little shale; contains grahamite in Black Fork Mountain.

4. Standley shale, 5,000 feet thick; composed of blue, black, and greenish shales and friable drab sandstone. Contains grahamite veins in Jackfork, McGee Creek, and Impson valleys.

The Carboniferous rocks occupy all of the region except the areas mentioned below as containing Ordovician, Silurian, and Devonian rocks.

DEVONIAN AND SILURIAN ROCKS.

Small areas of Silurian and Devonian cherts and black shales occur in the northwestern part of T. 2 N., R. 15 E., and in the corresponding part of T. 3 N., R. 17 E. Chert of probable Devonian age

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crops out near the northeast corner of T. 1 N., R. 13 E., and in the northeastern part of T. 4 N., R. 21 E.

ORDOVICIAN ROCKS.

5. Talihina chert, 1,200± feet thick; composed of light-colored novaculitic chert at the top, greenish shales in the central part, and bluish-black bituminous chert and shale in the lower part. The greenish shale in the center part of the formation contains the grahamite deposits north of Atoka.

6. Stringtown shale, 600± feet exposed, consisting of black and blue shales. The lower part of the formation is concealed.

The Ordovician rocks of the region crop out in the Potato Hills, which are about 50 square miles in extent and lie between Winding Stair and Kiamichi mountains, opposite Tuskahoma, and in a single ridge at the extreme west end of the Ouachita Mountain region just west of the Missouri, Kansas and Texas Railway.

STRUCTURE.

The rocks of the Ouachita region have been crumpled into many folds, to which are due the arrangement and the location of the principal mountains and valleys. In addition to the folding, the rocks have been fractured and in places faulted. In certain localities some of the fractures have opened as fissures and have received deposits of bitumen that are now classed as "grahamite." The grahamite-bearing fissures in south-central Oklahoma cut horizontal rocks and cross beds of shale and sandstone which in the vicinity are impregnated with bitumen.

DESCRIPTION OF DEPOSITS BY LOCALITIES.

IMPSON VALLEY.

The first discovery of grahamite deposits in paying quantity in Oklahoma (then Indian Territory) was made in 1897, on a branch of Tenmile Creek, in the west side of Impson Valley, near the south side of sec. 21, T. 1 S., R. 15 E. In the following year the lands, including the deposits of grahamite, were taken under an asphalt lease and operations were begun on a vein 20 to 25 feet thick. Samples of the mineral were collected in 1898 from the workings at a depth of 30 feet. These samples were analyzed and tested by William C. Day, and the tests revealed certain properties closely related to those of albertite. The results of these tests were published in a paper by the writer.[a] The following comparative data, derived from statements

[a] Taff, J. A., An albertite-like asphalt in the Choctaw Nation, Indian Territory: Am. Jour. Sci., 4th ser., vol. 8, 1899, pp. 219–224.

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in Dana's manual pertaining to albertite from Nova Scotia and from the results of the tests by Doctor Day, are submitted to show the relations of the two substances:

Physical properties and composition of Nova Scotia albertite and Impson Valley grahamite.

	Albertite.	Grahamite.
Physical properties.		
Specific gravity	1.097	1.175
Color	Jet black.	Jet black.
Softens in boiling water	A little.	Does not.
In candle flame	(a)	(b)
Soluble in alcohol	Trace.	Trace.
Soluble in ether, per cent	4	5.34
Soluble in turpentine, do	30	(c)
Composition.		
Carbon (Weatherill), per cent	86.04	86.57
Hydrogen (Weatherill), do	8.96	7.26
Nitrogen:		
(Weatherill), do	2.93	.....
(Day), do	1.84	1.48
Sulphur:		
(Weatherill), do	Trace.	.....
(Day), do	0.17	1.38
Oxygen (Weatherill), do	1.97	2.00
Ash (Weatherill), do	0.10	1.31

[a] Shows incipient fusion.
[b] Shows incipient fusion; takes fire and burns a short time after removal of flame.
[c] Almost insoluble.

The only important difference in the two materials as shown by these tests is in their solubility in turpentine. Accordingly, Doctor Day concluded that the material resembles the albertite from Nova Scotia more than other asphaltic bodies which had thus far been investigated.

There are some further distinctions in the physical properties of albertite and the solid bitumen of Oklahoma. Albertite usually has a bright luster, is massive or compact, and has smooth fractures. The absence of these features in the Oklahoma material, however, may be due in part at least to the fact that it has suffered crushing since it was solidified. Albertite and the Oklahoma bitumen are also very distinct from one another in degree of solubility in carbon disulphide and naphtha. The bitumen in albertite is soluble only to a small extent in carbon disulphide, but the Impson Valley material is almost completely so. In this and many other respects the Oklahoma solid bitumen corresponds most closely with grahamite from the type locality in Richie County, W. Va., as has been worked out by Richardson.[a] A proximate analysis of the Impson Valley grahamite will be found on page 296.

The solid bitumen of Oklahoma that has been mined commercially is classed in the trade as grahamite, and it is probably true that all

[a] Richardson, Clifford, Modern asphalt pavement, New York, John Wiley & Sons, 1908,

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the deposits, with the possible exception of that in Black Fork Mountain, fall within this class, though it is known that variations in composition are shown by solid bitumen occurring in separate localities in the same region, and even in a single mine from the surface downward if considerable depth has been attained. Such changes are regarded to have been brought about by the loss of the more volatile substances. On the assumption that all the bitumen has the same source, differences in the character of the rocks adjoining the vein, variations in the structure of the rocks, and differences in the time at which the deposits were introduced into the fissures would tend to produce variations in composition.

The rocks in which the grahamite occurs in Impson Valley are near the top of the Standley shale. The formation has been strongly folded upward and thrust over slightly toward the west. The strata have been fractured and probably faulted along a belt parallel with the axis of the fold and near the west side of the valley. The beds of shale and sandstone contiguous to the veins have suffered crushing and shearing to such an extent that they are retained in the walls of the mines with great difficulty after the grahamite has been extracted. Strong pressure has been exerted on the rocks since the bitumen became solid, thereby causing it to be fractured and intimately jointed. The grahamite veins are lenticular and variable in form, both laterally and vertically. The strike of the veins has a general north-south direction, parallel with the general trend of the rocks, but not necessarily parallel with the individual beds. The pitch of the veins is steep toward the east, in the direction of the dips of the rocks, but usually at a greater angle. These veins have been exploited more or less continuously since 1898.

JACKFORK VALLEY.

An important discovery of grahamite was made recently in the broad, flat valley of Jackfork Creek, near the center of the east side of sec. 9, T. 2 N., R. 18 E., on a low swell produced by the outcrops of certain friable sandstone and sandy shale beds that occur in the central part of the Standley shale. The operators claim to have located the grahamite vein by prospecting three-fourths of a mile west and one-fourth mile east of the mine. The rocks at the place of discovery dip 37° S. and the vein, which is 19 feet thick at the surface, lies between even beds of sandy shales. At a depth of 140 feet in the main entry of the mine the vein turns downward, cutting the rock beds irregularly at a slope varying between 45° and 50°. Entries driven east and west from the main slope encounter rock masses that have fallen from the hanging wall when the bitumen was in a plastic or viscous state. In accordance with the general rule of grahamite or

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other solid-bitumen veins, the fissure which has been filled here is variable, both in lateral extent and in width, but its size has been determined only so far as exploitation has been carried. The vein varies also in structure. The central part, separated more or less irregularly by distinctions of structure from the grahamite above and below, is intimately jointed and affords an uneven granular surface closely resembling that of the Impson Valley grahamite. The product of this part of the vein, on account of the surface character, has a dull luster, though the luster of individual small facets is bright. The zone of the vein next to the foot wall has a columnar or pencillate structure, with a flatly conchoidal fracture developed perpendicular to the wall rock. The upper zone, in contact with the hanging wall, has a more distinctly conchoidal fracture and a more pronounced columnar structure than the lower zone. The same kind of structure also characterizes the material surrounding the larger rock masses that have fallen into the grahamite vein. Besides being more distinctly conchoidal in fracture than the zone of the vein in contact with the foot wall, this material has also a brighter luster. The upper and lower parts of the vein are brittle, like the other grahamite of the region. In contrast with the central part, the fracture and luster of the upper and lower parts of the vein resemble more closely those of albertite.

McGEE CREEK.

Two thin veins of grahamite, one 4 inches and another nearly a foot in thickness, were discovered in 1897 on the west side of the McGee Creek valley, in the SW. ¼ sec. 23, T. 1 N., R. 14 E. These veins are vertical and cut folded and crumpled green shales of the Standley. The strike of the veins is almost north and south, but the general trend of the rocks is east and west. The grahamite is friable and lustrous. Angular fragments of shale are mingled with the vein material as if crushing had occurred since the vein material had been introduced and become solidified. The deposits here have not been prospected sufficiently to prove their volume, but are of possible economic importance.

Two locations were made on a vein of grahamite in the valley of a tributary to McGee Creek late in 1905 or early in 1906—one in the northwest corner of sec. 30, T. 1 S., R. 14 E., and the other one-fourth mile farther south. At the former a shaft was sunk to a depth of 75 feet, according to report; but in 1906, when the locality was visited, it was almost filled with water and the vein could not be inspected. It is said to have been 4 feet thick in the shaft, from which several carloads of grahamite have been extracted. The vein at the second locality shows a thickness of 2 feet 6 inches and fills a

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fissure that extends in a north-south direction and dips 66° E., approximately with the bedding of the rocks.

These deposits occur in the Standley shale. The rocks, however, are but meagerly exposed in the vicinity. They have been crumpled and folded near these deposits. As stated above, the rocks at the southern prospect dip eastward, but 500 feet farther south the strata strike east and west and the rocks dip very steeply toward the south. A zone of faulting, in which the rocks to the south are thrust upon those to the north, has been traced eastward across McGee Creek and thence northeastward for a number of miles.

Specimens of grahamite float were collected from the shoals of McGee Creek in sec. 32, T. 1 S., R. 14 E., 2 miles south of the fault zone, an occurrence which suggests the presence of grahamite in the bed of McGee Creek not far upstream.

BLACK FORK MOUNTAIN.

Black Fork Mountain is composed of the Jackfork sandstone, a thick formation of many beds of sandstone interbedded with some layers of shale. The sandstone of Black Fork Mountain is tilted steeply toward the south. The structure of the mountain is that of a closed fold that has been overturned toward the north, or else of a monocline that is bounded on the south by a thrust fault of great displacement. The sandstone has been sheared and faulted at certain places in the south side of the mountain. An illustration of this condition may be seen in a quarry prospect near the base of the mountain southwest of the grahamite deposit, massive bituminous sandstones having been sheared and moved laterally on the fault plane. At the location of the grahamite deposit, also, the rocks are fissured and sheared.

The grahamite vein fills a fault fissure that bears in an irregular southwest course, cuts across the strata, and pitches steeply toward the southeast. The strike of the country rock is generally east and west. Faulting has developed also since the introduction of the bitumen into the fissure. At the northeast end of the main exposure the bitumen is abruptly terminated at a fault, where it abuts against thin beds of sandstone. This fault bears almost due south, the eastward extension of the fissure being displaced in a direction that is not determinable. Another fault 50 feet west of the first crosses the vein in a southerly direction. At this fault the strike of the vein changes from S. 45° W. to nearly S. 20° W. and so continues to the prospect. At the south end of the exposure a short prospect entry has been driven into the vein across sandstone beds that dip 60° S. 10° E. The vein at this point cuts across the strata with a pitch of 50°. At the outcrop it is 10 feet thick. A complete exposure of the vein

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was not revealed in the drift, but it is reported that 4 feet could be seen. These observations on the structure indicate a variable and highly disturbed vein deposit whose extent and volume under cover can be determined only by exploitation.

The physical properties of the bitumen deposit in Black Fork Mountain resemble those of the grahamite of Impson Valley and of the central part of the vein in Jackfork Valley. It is thoroughly black, is friable, and has a hackly fracture. The luster on the whole is not brilliant, but individually the small faces of the planes of fracture show a bright luster. A peculiar feature of the physical properties of certain parts of the vein is a banded structure, in which the planes of fracture in one band are parallel with one another but lie at divergent angles to similar sets of fractures in adjoining bands. The bitumen deposit of Black Fork Mountain has been metamorphosed to a greater degree than any other that has been tested in this region. A greater percentage of the more volatile part has been removed. On application of a particle of the bitumen to a candle flame it decrepitates, but does not fuse or become ignited like the Impson Valley or Jackfork Valley material. A comparison of the proximate analyses, given on page 296, shows that the percentage of carbon in the Black Fork Mountain product is much higher than that in the Impson Valley grahamite and is probably so high as to place it in a class of bitumens or so-called asphaltites other than that of grahamite. This fact will be determined, however, by tests of solubility and of chemical characteristics that have not yet been made at the Geological Survey or elsewhere so far as known to the writer. The high percentage of fixed carbon suggests that the material will be found practically insoluble by the media used in testing soluble bitumens.

FOURCHE MOUNTAIN, ARKANSAS.

Deposits of solid bitumen were located at the west end of Fourche Mountain, in Arkansas, about 12 miles east of the Black Fork Mountain locality. The place is about 1 mile east of Eagle Gap, which separates Black Fork Mountain from Fourche Mountain, and 2 miles east of Harris, on the Kansas City Southern Railway.

The deposits occur in a shear zone of shale and sandstone and are in the form of veinlets separated by crushed and slickensided shale. The bitumen product itself shows the effects of crushing forces, being sheared and slickensided. It resembles the solid bitumen of Black Fork Mountain, except that it is probably more friable. The proximate analysis below shows that it is more highly metamorphosed than the Black Fork Mountain product. The prospect from which the samples were taken, however, was shallow and without doubt the material had been affected by weathering agencies. The Fourche

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Mountain deposit is of no apparent economic value, in view of the structural conditions and the quality of the material.

The subjoined table affords a means of comparing the Fourche Mountain, Impson Valley, and Black Fork Mountain bitumens.

Proximate analyses of bitumens from Impson Valley and Black Fork Mountain, Oklahoma, and Fourche Mountain, Arkansas.

	Impson Valley, grahamite.	Black Fork Mountain, solid bitumen.	Fourche Mountain, solid bitumen.
Moisture	0.25	0.09	2.51
Volatile bitumen	43.33	23.06	17.78
Fixed carbon	55.97	75.90	79.15
Ash	1.45	.95	.56
Sulphur	1.47	1.69	1.38

BOGGY CREEK.

A vein of grahamite has been found in the valley of North Boggy Creek about 6 miles northeast of Atoka. The vein occurs in greenish clay shales of Ordovician age. These rocks are tilted steeply toward the east and the grahamite fills the fissure that extends between the beds, according to the report of a workman who was in charge of the property when the place was visited. A slope had been driven on the vein with the dip of the strata. The mine was not in operation and the slope was filled with water. The vein could not be inspected, but a quantity of the grahamite was stored ready for shipment. The thickness of the vein was reported to vary from a fraction of an inch to a few feet; the exact dimensions were not ascertained.

The physical properties of this bitumen are essentially the same as those of the Impson Valley grahamite. The material is black, has a bright luster, is brittle, and presents an irregular fracture. It takes fire and swells in a candle flame and continues to burn with a short flame for a moment after the candle is removed.

LOCO.

A grahamite deposit northwest of Loco is in sec. 6, T. 2 S., R. 4 W. So far as known it is found in a single vein that bears in a southwesterly course across the south half of the section. The country rocks consist of rather soft sandstone and shale that lie in a flat position. The grahamite vein cuts almost vertically across them. At a depth of 40 feet the vein cuts massive coarse bituminous sandstone, which crops out along the neighboring valley. Similar asphaltic sandstones occur in a large area in the vicinity of Loco.

Four shafts have been sunk on the vein, two in the southwest and two in the southeast quarter of sec. 6. The most easterly of the shafts was sunk to a depth of 96 feet, and the grahamite was mined by drifts run laterally on the edge of the beds. The mines were not

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in operation when the locality was visited, and they could not be entered on account of water. The keeper stated that the vein had an average thickness of 2 feet 6 inches and varied from an extreme of 10 feet 6 inches to a thin film. A reported output of 100 carloads of grahamite had been removed from the vein. It is said also that the vein had been traced by prospecting for a distance of half a mile. In this locality, as well as in others where the deposits occur in faulted rock, the thickness and extent of the vein can be determined only so far as exploitation has gone.

The grahamite in the Loco vicinity has physical characteristics very similar to those of the deposits in Impson, Jackfork, and Boggy valleys. It is black, brittle, lustrous, and friable. In a candle flame it fuses readily, swelling to several times its former size, and it continues to burn for a moment after the candle is removed.

RÉSUMÉ.

The grahamite deposits of southeastern Oklahoma occur as veins filling fissures in sandstone and shale, which lie in various positions from horizontal beds to those that are highly folded or tilted. The rocks that contain the grahamite occur in Ordovician and at several positions in Carboniferous sections. The bitumen deposits are known to vary in composition in three localities and probably vary from one to another of all the localities so far discovered. This variation is evidently due to differences in the degree of metamorphism, the progressive change brought about by the loss of the more volatile hydrocarbon. It is apparently not due to the age of the rocks in which the deposits occur. In a comparison of physical tests the grahamite in Ordovician shales near Atoka seems to be more nearly related to the Loco deposit in late Carboniferous rocks than to any other in the region. The deposits containing the highest percentages of fixed carbon occur in Black Fork Mountain, Oklahoma, and in Fourche Mountain, Arkansas, where they are either associated with sandstone or occur in closely folded and extensively fractured strata. In such relations the more volatile substances of the bitumen veins would escape with greater facility than where the material is in contact with shales and in association with less intense disturbance of the strata. The grahamite veins, like any other vein deposits, have been found to be variable in extent. They may be expected to vary in thickness in any direction or to terminate abruptly, for they occur in a region of faulted strata where both faulting and folding have progressed since the introduction of bitumen into the fissures. Thus far the only deposits that have warranted extended development and that are being worked at the present time are those in Impson and Jackfork valleys.

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SURVEY PUBLICATIONS ON ASPHALT.

The following list comprises the more important papers relative to asphalt published by the United States Geological Survey or by members of its staff. The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.:

BOUTWELL, J. M. Oil and asphalt prospects in Salt Lake basin, Utah. In Bulletin No. 260, pp. 468–479. 1905. 40c.

DAY, W. C. The coal and pitch coal of the Newport mine, Oregon. In Nineteenth Ann. Rept., pt. 3, pp. 370–376. 1899. $2.25.

ELDRIDGE, G. H. The uintaite (gilsonite) deposits of Utah. In Seventeenth Ann. Rept., pt. 1, pp. 909–949. 1896.

——— The asphalt and bituminous rock deposits of the United States. In Twenty-second Ann. Rept., pt. 1, pp. 209–452. 1901.

——— Origin and distribution of asphalt and bituminous-rock deposits in the United States. In Bulletin No. 213, pp. 296–305. 1903. 25c.

HAYES, C. W. Asphalt deposits of Pike County, Ark. In Bulletin No. 213, pp. 353–355. 1903. 25c.

HILGARD, E. W. The asphaltum deposits of California. In Mineral Resources U. S. for 1883–84, pp. 938–948. 1885. 60c.

HOVEY, E. O. Asphaltum and bituminous rock. In Mineral Resources U. S. for 1903, pp. 745–754. 1904. Idem for 1904, pp. 789–799. 1905.

RICHARDSON, C. Asphaltum. In Mineral Resources U. S. for 1893, pp. 626–669. 1894. 50c.

SMITH, C. D. (See Taff, J. A., and Smith, C. D.)

TAFF, J. A. Albertite-like asphalt in the Choctaw Nation, Indian Territory. Am. Jour. Sci., 4th ser., vol. 8, pp. 219–224. 1899.

——— Description of the unleased segregated asphalt lands in the Chickasaw Nation, Indian Territory. U. S. Dept. Interior, Circular No. 6. 14 pp. 1904.

——— Asphalt and bituminous rock. In Mineral Resources U. S. for 1906, pp. 1131–1137. 1907. 50c.

——— Asphalt and bituminous rock. In Mineral Resources U. S. for 1907, pt. 2, pp. 723–730. 1908.

TAFF, J. A., and SMITH, C. D. Ozokerite deposits in Utah. In Bulletin No. 285, pp. 369–372. 1906. 60c.

VAUGHAN, T. W. The asphalt deposits of western Texas. In Eighteenth Ann. Rept., pt. 5, pp. 930–935. 1897.

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BUILDING STONES.

MARBLE PROSPECTS IN THE CHIRICAHUA MOUNTAINS, ARIZONA.

By Sidney Paige.

INTRODUCTION.

The following report is the result of an investigation made at the request of the Supervising Architect of the Treasury, through the United States Geological Survey, the writer spending four days in the field during the latter part of December, 1908. Arrangements made by Mr. John G. Kerr, of Bowie, Ariz., the manager of the properties examined, served greatly to facilitate field movements and added much to the pleasure of the undertaking. For this cooperation grateful acknowledgment is here extended.

GEOGRAPHY AND TOPOGRAPHY.

The properties examined are situated in Cochise County, Ariz., in the Chiricahua Mountains, a range which trends in a general northwest-southeast direction. These mountains rise abruptly from desert valleys—the San Simon on the northeast and the Sulphur Springs on the southwest. (See fig. 24.)

The main line of the Southern Pacific Railroad passes about 12 miles from the north front of the range, and the El Paso and Southwestern Railroad passes about the same distance from the eastern front at a point where it begins to curve to the south. The properties examined may be described in two groups—first, those accessible from Bowie, Ariz., and located about 14 miles S. 22° E. from that town; second, those located about 18 miles N. 50° W. from Rodeo, N. Mex., a station on the El Paso and Southwestern Railroad.

The claims of the first group lie in a belt which stretches westward from Emigrant Canyon to a point several miles beyond old Fort Bowie; those of the second group lie near the head of Whitetail Can-

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yon, a short distance south of Cochise Head. The Chiricahua Range and its northwestward continuation, the Dos Cabezas Mountains, rise abruptly from desert valleys. From an elevation of 3,750 feet at Bowie the valley slopes almost imperceptibly at first, and then at a

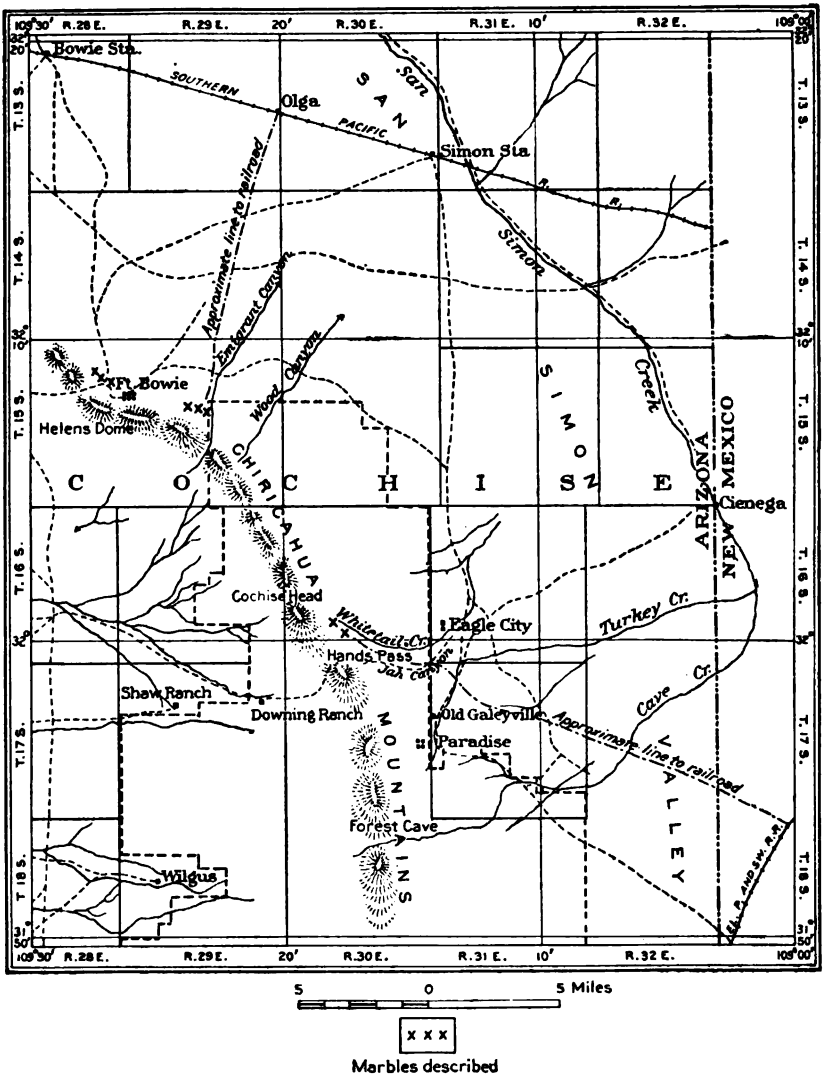

FIGURE 24.—Map showing location of marble prospects in Chiricahua Mountains, Arizona.

slightly steeper grade, upward to an elevation of about 4,400 feet at the base of the mountain scarp. From this point, on entering the range, one passes immediately to mountain topography—steep slopes, high stream gradients, and peaks that rise several thousand feet above the plains. All the drainage, flowing both south and north, is lost soon

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after leaving the mountain front in immense compound alluvial fans, such as characterize so many of these western deserts. The trend of the range is determined largely by the attitude of the rocks composing it. These are sedimentary beds, striking northwest and dipping to the southwest at an average angle of 45°. The range is narrow, as compared with its length, but its shape is modified to the south and north by intrusive igneous masses, and in very general terms that portion of the range lying near Fort Bowie owes its configuration to resistant beds of conglomerate and quartzite, through which cross-cutting streams have incised sharp canyons.

GEOLOGY.

GENERAL STATEMENT.

The rocks occupying the area under discussion are entirely of sedimentary origin, though igneous masses are known to exist at no great distance. They comprise, it is believed, strata of at least three geologic periods and possibly a fourth. The following notes are con-

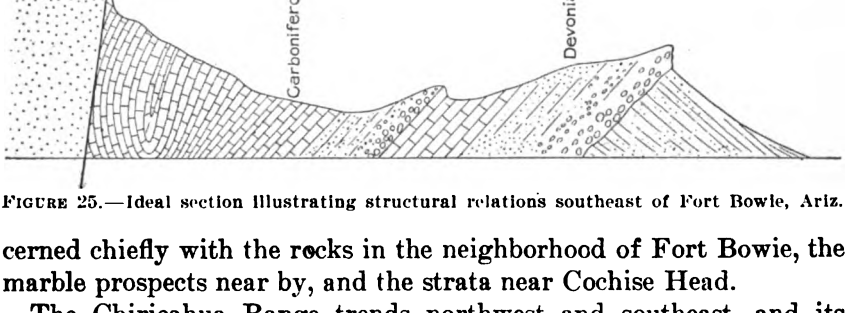

FIGURE 25.—Ideal section illustrating structural relations southeast of Fort Bowie, Ariz.

cerned chiefly with the rocks in the neighborhood of Fort Bowie, the marble prospects near by, and the strata near Cochise Head.

The Chiricahua Range trends northwest and southeast, and its northeast front is composed of stratified rocks with a like trend. A general section through the range a short distance southeast of Fort Bowie is shown in figure 25. The outer ridge presents two unconformable series, the older one dipping northwest at angles near 40° and the younger dipping southwest at angles varying between 30° and 60°. The unconformity between these two series is striking and is accentuated by the presence of a massive basal conglomerate which rests upon the eroded edges of the older beds and weathers into conspicuous cliffs.

Farther southwest a second and rather unusual unconformity may be observed. It occurs at the top of the younger of the two series just described and consists in an abrupt change of sediments. A fine-grained, massive blue limestone of considerable thickness is followed by a heavy conglomerate bed, which so far as could be observed was

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perfectly concordant in both strike and dip with the rocks that lay below it and whose contact with the limestone could be traced for miles. Another series of beds succeeding this conglomerate are terminated to the southwest by a second abrupt change, but here a heavy mass of quartzites takes the place of the limestone. This quartzite mountain mass, it is believed, owes its position to faulting, and the attitude of the beds composing it is not concordant with that of the limestone, the strike being N. 15° E. and the dip nearly vertical. (See fig. 25.)

STRATIGRAPHY.

The rocks of the lowest formation—that is, the one which forms the northeast range front—are apparently metamorphic sediments, and include possibly some volcanic rocks. They do not in the area observed form sharp outcrops, but in general present débris-covered slopes, which merge with the desert to the northeast. They are believed to represent the oldest rocks in the area studied.

The series unconformably overlying these rocks comprises a basal conglomerate, transition beds, fine quartzites, siliceous limestones, and limestones. The conglomerate, which is variable in thickness but probably does not exceed 25 feet in any place, consists of well-rounded pebbles ranging from an inch to a foot in diameter, an average probably being about 4 inches. The matrix of this conglomerate forms a minor part of the rock, and the pebbles are composed almost entirely of siliceous material, a condition which, it is believed, may largely be the result of secondary alteration. This conglomerate outcrops in a rough bluff on the outer ridge of the range.

Overlying the conglomerate is a thin series of beds intermediate in character between that rock and the quartzites which follow. The quartzites range in color through light yellows to dark brown, and are composed of well-banded, fine-grained, extremely hard siliceous material. The thickness of these beds is probably a thousand feet. They are followed by limestones with siliceous layers and nodules, which in turn grade into pure limestone.

The limestones are important because of their economic bearing. They are somewhat variable in character, the variation consisting largely in the presence or absence of siliceous material. At some horizons, however, the rock is fairly free from this impurity, and in general the beds are fine grained and dark blue in color, with a few narrow fossiliferous bands.

A second conglomerate (see fig. 25) introduces the next series of beds. It is of much the same nature as that already described, averages about 20 feet in thickness, and is marked generally by a bold outcrop. In some places it does not appear, though it may exist below the surface. This disappearance may possibly be due to an actual

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absence of the beds; if so, the origin of the conglomerate can be assigned to stream débris deposited upon a shallow-water limestone. The pebbles are well rounded and the absence of a matrix is generally remarkable. Pebbles which are now entirely silicified show markings peculiar to certain marbles from the overlying beds, to be described later. Quartzites, shales or their metamorphic equivalents, and limestones comprise the succeeding strata.

The last and fourth series, the unconformable quartzites, outcrop in a bold mountain mass. Their aggregate thickness is much greater and their bedding planes are less pronounced than those of the quartzites already described, but lithologically these rocks are very similar to the older quartzites.

Little is known concerning the age of the several series described above. E. T. Dumble[a] has shown that Carboniferous and Devonian rocks occur in the Chiricahua Mountains. Referring to the Carboniferous rocks, in the Swisshelm Mountains, he says: "In the Chiricahua Mountains on Cave Creek above Mr. Reed's house we found exposures of platy limestone resembling that at the base of these beds." And again: "North of this, between Cave Creek and Turkey Creek, the exposures of Carboniferous limestones are very satisfactory. They dip southwest from 30° to 45°; and the section is repeated by the occurrence of faults." "The rocks which underlie the Devonian in the Dragoon Mountains and which we found to occur both in the Mule and Chiricahua mountains were not differentiated."

It is assumed for the present, then, that the limestone series figured in the ideal section (see fig. 25) represents strata of Devonian and Carboniferous age.

STRUCTURE.

As the area which came under observation is small, conclusions regarding the broad structural features are presented with a certain degree of reluctance and can not be regarded as final. It is believed, however, that at least a sound basis for future investigations has been reached.

Figure 25 presents the structure of the series described above, in ideal section. Up to the point where a syncline is shown the beds are monoclinal and have a northwest trend, with dips varying between 30° and 60°. The evidence for synclinal structure follows. A view from the northwest of Limestone Mountain, a peak occupying a stratigraphic position corresponding to the uppermost limestones, shows clearly that its summit is the center of a syncline, and the strikes and dips observed on its slopes accord with this conclusion. These strikes and dips indicate, moreover, that the syncline pitches to the southeast, and it was noted that toward the northwest

[a] Notes on the geology of southeastern Arizona: Trans. Am. Inst. Min. Eng., vol. 31, 1902, p. 713.

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the strata involved were in part cut out—that is, the base of the beds, or such part as was included in the fold, had been removed by erosion. One standing on the summit of Limestone Mountain and looking northwest may observe synclinal structure a short distance from the unconformable quartzite contact, and an overturning of the southern limb of the fold is strongly suggested. Both the summit of Limestone Mountain and the rocks near the quartzite contact are characterized by a lack of bedding and a general crushed condition, phenomena characteristic of a synclinal axis. Finally, to the southeast were noted minor folds that complicate the structure in the vicinity of the marble prospects.

Quartzite Mountain, it is believed, owes its elevated position to faulting, probably contemporaneous with the folding and due to similar forces of compression. The fault plane, so far as could be judged, is curving and more or less nearly vertical.

METAMORPHISM.

Two effects of metamorphic processes are noteworthy within this area. Marble zones have been formed in the limestone strata, and silicification on a large scale is believed to have taken place. As the latter process does not concern the present report it will be discussed very briefly. It was noted that certain limestone beds in the lower series disappeared along the strike in a southeasterly direction, but that in that vicinity there were some entirely silicified bowlders marked in patterns precisely like those in the marble zones, a fact which suggests that silicified beds now represent these limestones. As evidence of faulting to account for the disappearance of the limestones did not appear, it is presumed that owing to the presence of igneous masses, which exist in the near vicinity, or through the agency of circulating waters acting during the period in which these rocks were deeply buried, a siliceous replacement of the marble and limestones of the lower series has taken place on a large scale.

The marble zones in the limestone are of wide extent. Their formation may be adequately accounted for as resulting from the effects of heat, either developed during the process of folding or emanating from intrusive masses. A combination of the two causes affords the most plausible explanation. The process resulted in a complete recrystallization of the rock, a change of color, generally from blue to white or pink, and a segregation of the carbonaceous matter in fine markings, which add to the beauty of the stone. The zones are of the nature of more or less extended beds within the limestone strata, and as they owe their existence to metamorphic forces they are not confined to any one horizon. Both their quality and their extent are variable, but in general they conform in dip and strike with the limestones.

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MARBLE.

INTRODUCTION.

The marble prospects visited by the writer may conveniently be grouped under three heads, which will be described separately. They may be called the western marbles—those west of Fort Bowie, in Devonian rocks; the central marbles—those near the head of McIntosh Canyon (a tributary of Emigrant Canyon), in Carboniferous rocks; and the southern marbles—those at the head of Whitetail Canyon, near Cochise Head, also believed to occur in Carboniferous rocks.

WESTERN MARBLES.

Distribution.—The western marbles occupy a stratigraphic position near the top of the Devonian and extend northwestward from Fort Bowie in a more or less regular band for several miles. The portion examined by the writer is almost wholly within one holding, the Sienna group of claims, a tract of 160 acres. The ledge varies in width between 50 and 75 feet and dips to the southwest at about 60°. The topography is rugged and the outcrop is continuously exposed on hillsides and ridges and in valleys.

Composition and appearance.—No analyses are at hand, but the rock is probably a nearly pure carbonate of lime, with medium-grained, crystalline-granular structure, and for the most part of a pure white color with pinkish tones. Impurities in the form of narrow seams of red iron oxide are abundant but present a very beautiful appearance and if the rock is used for decorative purposes might under suitable conditions greatly enhance its value. On the borders of the ledge the colors range through grays to blues. The lack of silica bands is noteworthy.

Jointing.—Unfortunately, the greater part of this exposure reveals extensive jointing. The joints vary greatly in their direction, and no regularity that might aid in the extraction of the material was observed. In a few localities these joints are on the whole less pronounced and more solid rock might be expected with increasing depth, but a number of prospect pits blasted out along the outcrop all reveal a similar condition of severe fracturing.

In view of the possibilities of a diminution in the number of joints in depth and of the beauty of the stone for ornamental purposes, the ledge deserves prospecting. It is possible that at a depth of perhaps 30 feet, even though the seams should still occur, commercial slabs might be obtained by careful handling. Considerable work with a core drill is needed to prove the commercial value of these deposits.

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CENTRAL MARBLES.

Distribution.—The central marble properties are comprised in two 160-acre tracts, the Pavonazzo and Pentelicus groups of claims. The two tracts, joined end to end, have a northwest-southeast trend and extend from a tributary of Emigrant Canyon over a divide into the valley of a second stream. Marble exists in this general area at localities other than within these boundaries, but the following remarks refer especially to these two groups.

Marble in ledges of varying widths is present for practically the entire length of the two claims, a distance of about 1¾ miles, and occurs as bands and lenses in a fine-grained blue limestone. The ledges accord in strike and dip with the limestone—that is, they trend northwest and have steep dips to the north, a dip at variance with the beds farther northwest and due to some structural feature not at present determined.

Though synclinal structure is known to exist in the near vicinity, a detailed study of the beds near the marble leads to the conclusion that the deposits are of such thicknesses as to insure sufficient material for many years, provided that in depth metamorphism has been equally effective in altering the limestone to its condition shown at the surface. The length and width of the outcrop and the attitude of the beds seem to justify the assumption of a continuance of the surface conditions for considerable depths.

Composition and character.—An analysis of the marble from the Pavonazzo claim shows the stone to be a practically pure carbonate of lime, containing 99.98 per cent of $CaCO_3$.[a] All evidence of original bedding has disappeared from the stone, which is now a massive, even, crystalline-granular, medium-grained aggregate of calcite crystals, the separate crystals being plainly visible with the unaided eye. The dominant color is white, or pinkish or grayish white, with irregular black markings. Gray, dove-colored, and blue varieties may also be seen, and areas are found where pure-white material can be extracted. As compared with eastern marbles, many specimens of which were examined in the collection of the United States National Museum, the black marking is generally more clear cut and finer and the base clearer. A comparison with the only two available specimens of the Italian Pavonazzo marble shows that in the Arizona rock the base is crystalline as opposed to waxy, the markings are not so perfectly black and clear cut, and the general appearance is not so rich. The rock is, however, handsome, and individual taste must be used in comparisons. The availability of several varieties may be considered a distinct advantage in commercial exploitation.

[a] Oral statement by Mr. Kerr.

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It has been pointed out that the marble zones occur as lentils or beds in limestone strata, and as many of these strata are characterized by bands of siliceous material, the marbles likewise contain them. These siliceous bands are variable in length, thickness, and number. They may completely destroy a body of marble or they may be so scattered as to be of no appreciable harm. All gradations exist between these conditions, but the bands have in common one desirable property—they accord with the strata in strike and dip. The commercial availability of a piece of marble, therefore, depends on the presence or absence of these bands, and the number that may be considered permissible must be determined by future developments. As shown elsewhere, a number of localities are entirely free from them. Other than the siliceous bands, no deleterious constituents of the rock were observed, pyrite being noteworthy by its absence.

Weathering.—The rock has excellent weathering qualities in the climate of Arizona. For the most part the merest film has formed on the surface, and when this is broken through the fresh, hard white stone is revealed. On a block that was blasted from a prospect pit and had lain two years and four months exposed to the elements no effects of weathering could be noted with the naked eye.

Jointing.—Observations on jointing are by their nature superficial, and must be accepted with an understanding of the meager data on which they are based—generally surface indications. Like the siliceous bands already mentioned, the joints vary in abundance and distribution, locally being so numerous as to give little hope of commercial stone, but elsewhere being so nearly lacking that a good body of rock is assured. Evidence gathered in the only two openings made on these properties indicated, in a measure, that many surface joints would give out in depth. At other places the peculiar rounded form and great solidity of the weathered blocks suggested a shallow depth for many joints. No definite system could be established, though locally the parallelism of the joints may aid in quarrying. This matter will be again mentioned in the descriptions of localities.

The presence of siliceous bands is the only obstacle to the easy extraction of the marble. As channeling machines would be used, the regularity in strike and dip of such bands, if they existed in the area selected, would assure at least one direction of unobstructed cutting. They in a measure determine the manner of quarrying, but should not seriously interfere with exploitation if wide bands of pure marble are present between them. The writer is informed that the stone works freely.

Special localities.—The localities of greatest promise on the Pavonazzo and Pentelicus claims are situated on a nearly continuous

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body of marble, more or less of which is available. This area, beginning near the southeast end of the Pavonazzo claim, in the sharply incised valley of a small stream, extends up the steep slopes of a hillside, over a divide, and down the slopes on the southeast side. Within this area several bodies of marble exist, quite or nearly free from silica and in some places entirely free from joints. It should be noted that there is practically no overburden and that the cutting away of the rather sparse underbrush will permit an immediate attack on the solid stone, though naturally the upper cuts would not be used.

On the Pavonazzo claim a ledge of marble 75 feet thick, about 250 feet long, and generally free from silica may be seen. The rock is white and pinkish white with black markings, but some grays are also present. Weathering reveals more or less jointing, north and south, N. 30° E., and in other directions; but the writer believes that much of this jointing will disappear in depth, or at least that it will not interfere with the obtaining of commercial slabs. From this locality, by blasting, which naturally shatters the rock and would not be employed in quarrying, slabs over 6 feet long and 2 feet wide were obtained. Six slabs 5 by 2 feet were also taken out. The various markings on these slabs lend themselves readily to the designer's skill and beautiful effects in matching have been produced.

To the southeast, up the steep hillside, a fine ledge of marble may be observed. Within it at two localities, and perhaps more, a quarry floor could be opened. A thickness of 30 to 50 feet and a length of at least 75 feet are conservative figures for bodies of marble practically solid and free from silica in this ledge; and there can be no doubt as to their continuance in depth, for the outcrop of the ledge climbs a steep slope. It is reasonable to suppose that as depth is attained the linear extent of available commercial rock will be considerably increased. The character of the stone is essentially the same as that of the ledge just described.

The Pentelicus claim comprises, perhaps, the best prospects in this region. The marble here has taken more the form of an irregular mass, not being confined between regular walls of limestone. For a width of about 300 feet and a length of at least 500 feet, it presents several areas where quarries might be opened. Two areas, selected because of their general freedom from silica in bands, were noted where a floor 100 by 100 feet might be started, and though silica is present, it should not interfere with the extraction of blocks of great size, larger than are usually demanded. As the brush which covers this outcrop has not been removed, it is reasonable to suppose that other equally good areas will be found. Jointing is not pronounced in the two areas mentioned, and probably grows less with depth. An

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opening made by blasting has revealed a white crystalline-granular marble with rich pink tints.

Considering the fact that all the above-described outcrops are in no sense other than surface showings, the prospect is very encouraging and there is no reason to believe that the deposits will not have ample depth, if the metamorphism which has converted the limestone to marble at the surface has extended throughout the mass of the rock. As has been pointed out, the marble zones are purely metamorphic developments in limestone strata, and structural evidence must be used with extreme caution as a basis for predicting continuity in depth; yet, in view of the length and breadth of the mass, it is reasonable and conservative to predict a large quantity of material. Other marble ledges were seen in the immediately adjacent region and two of them at least may develop into commercial properties.

In briefly summarizing, the following points should be noted:

The deposits are undeveloped surface showings and as such are promising. A minimum amount of dead work need be done; solid rock is at the surface in some localities and but a few cuts will be necessary to reach commercial stone. In other places where jointing is more pronounced, the valuable rock lies at greater depth. Silica bands are largely absent from a number of areas that might make quarry floors. In other areas large blocks for sawing could be taken out by cutting between the bands of silica. It must be said, however, that though silica in bands is the only detrimental material in the stone, it is one which must be thoughtfully considered, if the deposits are to be profitable.

Utilization.—The above-described marbles will probably be used for interior decorative purposes. It is believed that blocks of commercial size can be extracted, sawed into slabs, turned into columns, or fashioned to meet any of the general needs of architectural work.

Transportation.—The Pentelicus claim, on which development will probably be first undertaken, is 14½ miles from Olga, a point on the Southern Pacific Railroad 9 miles east of Bowie. About 3½ miles of this distance is within the mountains, and in building a road for a traction engine the ordinary difficulties encountered in such country will have to be overcome. The 11-mile stretch from the base of the mountains to the railroad presents no difficulties other than those attached to the building of a road on an even down grade over an alluvial fan. The mountain work from the Pavonazzo claim will be a little more difficult, but the problems involved are essentially the same. The writer is informed that the rates to eastern centers, via the Gulf, are sufficiently low to make the industry profitable.

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SOUTHERN MARBLES.

Location.—The marble of the southern area occurs near the head of Whitetail Canyon, on its southwest side. The property examined is called the Cochise marble placer and is accessible from the El Paso and Southwestern Railroad. It lies about 18 miles N. 50° W. from Rodeo, N. Mex., and about 5 miles northwest of Paradise, Ariz. The ledge can be traced for a mile and occurs as a band in a series of northwest-southeast trending Carboniferous (?) limestones.

Composition and appearance.—No analyses of the rock are at hand, but its manner of weathering and appearance indicate that it is probably a nearly pure calcium carbonate. It is a coarsely crystalline-granular white marble, without markings. On the surface when broken and in a pit opened by drilling and blasting the material revealed is a dead white.

Limonite stains were seen in the open cut, the streaks running parallel to the strike, but only two were observed within a vertical distance of about 15 feet. Silica, in bands, occurs in a similar manner to that already described. At the base of the ledge about 100 feet is entirely free from this impurity. A narrow band of silica is then succeeded by about 50 or 60 feet of clean stone, and from this point up silica is rather abundant. With slight variations this condition exists throughout the claim.

Weathering.—The rock shows slightly more decomposition at the surface than does that of the Pavonazzo and Pentelicus claims. Though this condition seems variable, probably on the removal of 20 or 30 feet of rock the stone will be seen at its best, lacking what might be characterized as a slightly dull appearance in the surface rock.

Jointing.—The deposit is remarkably solid and generally free from such joints as would materially affect its extraction.

Utilization.—The ledge outcrops on a hillside above the gulch and, though no appreciable overburden exists, probably 20 or 30 feet will have to be removed before the best stone is reached. If its weathering qualities, of which no tests are available, prove satisfactory, the material should make excellent building stone. Its quality as a decorative material must be decided by samples submitted to those desiring to use the stone. The quantity is assured so far as surface conditions and geologic structure can be used as criteria, and blocks of any size may be extracted.

Transportation.—A road for a traction or other engine would have to be built a distance of 18 miles to reach the nearest railroad.

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TESTS.

The following tests were made at the structural-materials laboratories of the Geological Survey at St. Louis:

Results of tests on marble from the Arizona marble quarry, Bowie, Cochise County, Ariz.

No. of test piece.	Compression test.					Weight ratio of absorption.		
	Position in machine.	Lateral dimensions (inches).	Height (inches).	Ultimate strength (pounds per square inch).	Modulus of elasticity.	30 minutes.	24 hours.	48 hours.
1	On bed	2.06 by 2.06	2.07	10,430	2,100,000	0.0010	0.0010	0.0010
2	do	2.06 by 2.07	2.08	11,500	2,175,000	.0011	.0011	.0011
3	do	2.07 by 2.07	2.07	12,000	2,350,000	.0011	.0011	.0011
Average				11,310	2,208,000	.0011	.0011	.0011
4	On edge	2.06 by 2.08	2.08	8,480	1,500,000	.0010	.0010	.0010
5	do	2.11 by 2.07	2.09	10,000	1,775,000	.0011	.0011	.0011
6	do	2.09 by 2.11	2.10	9,400	2,450,000	.0010	.0010	.0010
Average				9,290	1,908,000	.0010	.0010	.0010
General average				10,300	2,058,000	.0011	.0011	.0011

No. of test piece.	Volume ratio of absorption.			Absolute pore space = 1 − density.	True specific gravity.	Apparent specific gravity.	Weight per cubic foot (pounds).
	30 minutes.	24 hours.	48 hours.				
1	0.0027	0.0027	0.0027	.....	2.721	2.709	168.91
2	.0030	.0030	.0030	.....	2.719	2.707	168.80
3	.0029	.0029	.0029	.....	(a)	2.711	169.05
Average	.0029	.0029	.0029	.....	.....	2.709	168.92
4	.0028	.0028	.0028	.....	(a)	2.708	168.86
5	.0030	.0030	.0030	.....	(a)	2.708	168.86
6	.0027	.0027	.0027	.....	(a)	2.710	168.99
Average	.0028	.0028	.0028	.....	.....	2.709	168.90
General average	.0029	.0029	.0029	0.0041	2.720	2.709	168.91

(a) Only 2 tests made.

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SURVEY PUBLICATIONS ON BUILDING STONE AND ROAD METAL.

The following list comprises the more important publications on building stone and road metal by the United States Geological Survey. These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The annual volumes on Mineral Resources of the United States contain not only statistics of stone production, but occasional discussions of available stone resources in various parts of the country. Many of the Survey's geologic folios also contain notes on stone resources that may be of local importance.

ALDEN, W. C. The stone industry in the vicinity of Chicago, Ill. In Bulletin No. 213, pp. 357–360. 1903. 25c.

BAIN, H. F. Notes on Iowa building stones. In Sixteenth Ann. Rept., pt. 4, pp. 500–503. 1895.

BASTIN, E. S. (See Leighton, Henry, and Bastin, E. S.)

BURCHARD, E. F. Concrete materials produced in the Chicago district. In Bulletin No. 340, pp. 383–410. 1908.

COONS, A. T. Stone. In Mineral Resources U. S. for 1907, pt. 2, pp. 563–605. 1908.

DALE, T. N. The slate belt of eastern New York and western Vermont. In Nineteenth Ann. Rept., pt. 3, pp. 153–200. 1899. $2.25.

——— The slate industry of Slatington, Pa., and Martinsburg, W. Va. In Bulletin No. 213, pp. 361–364. 1903. 25c.

——— Notes on Arkansas roofing slates. In Bulletin No. 225, pp. 414–416. 1904. 35c.

——— Slate investigations during 1904. In Bulletin No. 260, pp. 486–488. 1905. 40c.

——— Note on a new variety of Maine slate. In Bulletin No. 285, pp. 449–450. 1906. 60c.

——— Recent work on New England granites. In Bulletin No. 315, pp. 356–359. 1907.

——— The granites of Maine. Bulletin No. 313. 202 pp. 1907.

——— The chief commercial granites of Massachusetts, New Hampshire, and Rhode Island. Bulletin No. 354. 228 pp. 1908.

——— The granites of Vermont. (In preparation.)

DALE, T. N., and others. Slate deposits and slate industry of the United States. Bulletin No. 275. 154 pp. 1906. 15c.

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DARTON, N. H. Marble of White Pine County, Nev., near Gandy, Utah. In Bulletin No. 340, pp. 377–380. 1908.

——— Structural materials near Portland, Oreg., and Seattle and Tacoma, Wash. Bulletin No. 387. — pp. 1909.

DILLER, J. S. Limestone of the Redding district, California. In Bulletin No. 213, p. 365. 1903. 25c.

ECKEL, E. C. Slate deposits of California and Utah. In Bulletin No. 225, pp. 417–422. 1904. 35c.

HILLEBRAND, W. F. Chemical notes on the composition of the roofing slates of eastern New York and western Vermont. In Nineteenth Ann. Rept., pt. 3, pp. 301–305. 1899. $2.25.

HOPKINS, T. C. The sandstones of western Indiana. In Seventeenth Ann. Rept., pt. 3, pp. 780–787. 1896.

——— Brownstones of Pennsylvania. In Eighteenth Ann. Rept., pt. 5, pp. 1025–1043. 1897.

HOPKINS, T. C., and SIEBENTHAL, C. E. The Bedford oolitic limestone of Indiana. In Eighteenth Ann. Rept., pt. 5, pp. 1050–1057. 1897.

HUMPHREY, R. L. The fire-resistive properties of various building materials. Bulletin No. 370. 99 pp. 1909.

KEITH, A. Tennessee marbles. In Bulletin No. 213, pp. 366–370. 1903. 25c.

LEIGHTON, HENRY, and BASTIN, E. S. Road materials of southern and eastern Maine. Bulletin No. 33, Office of Public Roads, Department of Agriculture. 1908. (May be obtained from Department of Agriculture.)

RIES, H. The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut. In Seventeenth Ann. Rept., pt. 3 (continued), pp. 795–811. 1896.

SHALER, N. S. Preliminary report on the geology of the common roads of the United States. In Fifteenth Ann. Rept., pp. 259–306. 1895.

——— The geology of the road-building stones of Massachusetts, with some consideration of similar materials from other parts of the United States. In Sixteenth Ann. Rept., pt. 2, pp. 277–341. 1895.

SIEBENTHAL, C. E. The Bedford oolitic limestone [Indiana]. In Nineteenth Ann. Rept., pt. 6, pp. 292–296. 1898.

——— (See also Hopkins, T. C., and Siebenthal, C. E.)

SMITH, G. O. The granite industry of the Penobscot Bay district, Maine. In Bulletin No. 260, pp. 489–190. 40c.

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CEMENT AND CONCRETE MATERIALS.

THE NIOBRARA LIMESTONE OF NORTHERN COLORADO AS A POSSIBLE SOURCE OF PORTLAND CEMENT MATERIAL.

By G. C. MARTIN.

INTRODUCTION.

SCOPE AND FIELD OF WORK.

The following paper is the result of a hasty and rather superficial examination of a small area made with a view of determining the possibility of local material being suitable for cement manufacture. The general geologic facts are drawn largely from publications by several geologists, notably Eldridge,[a] Darton,[b] and Fenneman.[c] The new material here presented is chiefly the chemical analyses and the local measurements and descriptions of the beds outcropping at localities from which samples were taken.

The area discussed in this paper is a narrow belt lying along the eastern face of the Rocky Mountains in Boulder and Larimer counties, Colo. As represented on the map (fig. 26), it includes part of the Great Plains on the east, part of the front range of the Rocky Mountains on the west, and a narrow foothill belt between. The area that was made the object of especial study is a narrower belt at the extreme western margin of the plains.

The mountains consist of granite masses having altitudes of 9,000 to 14,000 feet. The foothills, which form a narrow belt of linear

[a] Eldridge, George H., Mon. U. S. Geol. Survey, vol. 27, 1896.
[b] Darton, N. H., Prof. Paper U. S. Geol. Survey No. 32, 1905.
[c] Fenneman, N. M., Bull. U. S. Geol. Survey No. 265, 1905.

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monoclinal ridges parallel to one another and to the eastern front of the mountains, rise to elevations of 5,500 to 6,500 feet above sea level, or 500 to 1,500 feet above the general surface of the plains.

The part of the area lying in the plains constitutes an irregularly rolling country, with general maximum relief of 300 or 400 feet, the average elevation above sea level being about 5,000 feet. It is crossed from west to east by four large streams—Cache la Poudre River, Thompson River, St. Vrain Creek, and Boulder Creek—all of which rise within the mountains and are tributary to South Platte River at points east of the region here described. These streams furnish abundant water for irrigation, and consequently the plains are thickly settled and in a high state of cultivation. The chief towns of the region, all of which are located on the plains, are Boulder, Longmont, Berthoud, Loveland, and Fort Collins. These towns are on the main line of the Colorado and Southern Railway, which crosses the region here described from north to south. Longmont is also reached by a branch of the Burlington and Missouri River Railroad, and Boulder is the terminus of the Colorado and Northwestern Railroad and also of a branch of the Union Pacific. Boulder is about 20 miles northwest of Denver.

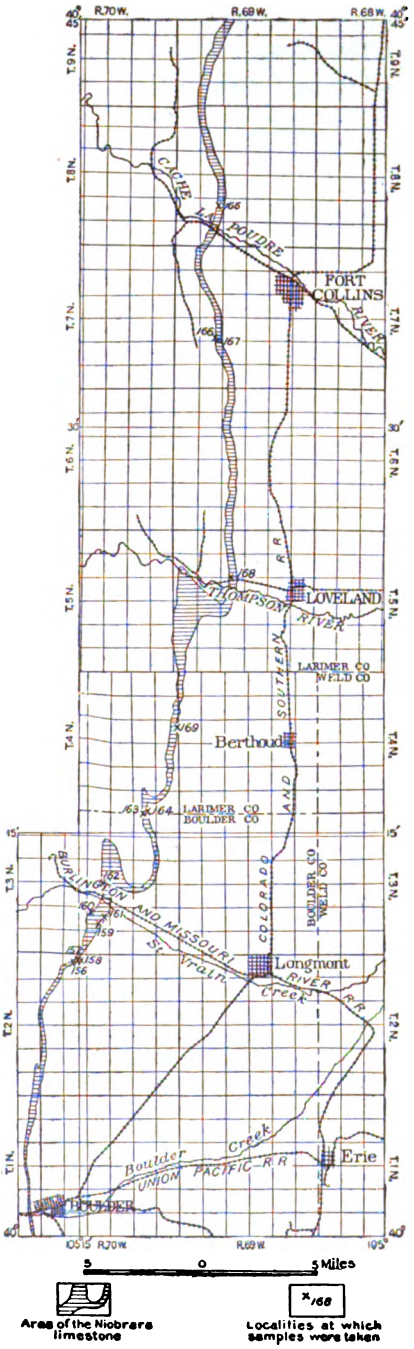

FIGURE 26.—Map of a portion of the foothill region of northern Colorado, showing areal distribution of Niobrara limestone.

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GENERAL GEOLOGIC RELATIONS.

The rocks of this region have been divided by Fenneman [a] into the following formations:

Quaternary	Alluvium and terrace gravels.
Cretaceous	Laramie.
	Fox Hills.
	Pierre.
	Niobrara.
	Benton.
	Dakota.
Jurassic	Morrison.
Triassic (?)	Lykins.
	Lyons.
	Fountain.
Algonkian	Quartzite of South Boulder Canyon.
Archean	Granites, etc.

Of these formations the pre-Cambrian granites and quartzite occupy the high mountains. The Fountain, Lyons, and Lykins formations, which constitute the so-called "red beds," and the Morrison and Dakota formations outcrop as steeply dipping beds in the foothills proper. The Benton group and Niobrara limestone also belong to the foothills belt where the limestones of the Niobrara are massive and make ridges; but to the plains where the Niobrara is less resistant. The Pierre, Fox Hills, and Laramie outcrop exclusively on the plains.

The pre-Cambrian rocks of this district consist of granite porphyry and granite gneiss, with local areas of quartzite and metamorphosed conglomerate. These constitute the floor upon which the sedimentary rocks were laid down.

Early Paleozoic limestones occur within this general region, though not within the special area here described. The nearest localities are in the vicinity of Colorado Springs. There is no evidence as to whether these rocks were deposited in this region and subsequently removed by erosion or whether this district was land during the period of their deposition.

The Fountain formation consists of granite arkose, quartzose sandstone, and some shale, all being characteristically red in color. It is now known to be of Carboniferous age. The thickness of this formation varies extremely within short distances, the limits being from a fraction of an inch to 1,500 feet, the general thickness in most places being 500 or 600 feet.

The Lyons sandstone and Lykins formation, which together constitute the "Upper Wyoming" of the older reports, consist of sandstones and sandy shales, with a few thin beds of limestone. These rocks, too, are generally reddish in color, many shades of red and in a few

[a] Fenneman, N. M., Bull. U. S. Geol. Survey No. 265, 1905, p. 20.

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places other colors being present. The Lyons formation is predominantly sandstone; the Lykins formation contains much sandstone, but also considerable shale and a little limestone. The thickness of the Lyons is about 300 feet; that of the Lykins is generally about 800 feet. The age of these formations is somewhat in doubt, but is either Permian or Triassic.

The Morrison formation consists of about 400 feet of sandstones, clays, and marls, all presumably deposited in fresh water. Several thin limestones are also present in this formation. The age of the Morrison is either Jurassic or Cretaceous.

The Dakota sandstone, which is one of the most characteristic beds of the foothills, consists of two massive beds of sandstone, with clay and shale intervening. The thickness of the whole is between 300 and 400 feet. The Dakota is of Cretaceous age.

The Benton group includes the Graneros, Greenhorn, and Carlile formations. It lies immediately above the Dakota and outcrops just east of it on the plains. The Graneros and Carlile consist of dark shales and some sandstone; the Greenhorn is a thin limestone, not well developed in this area. The local thicknesses are from 200 to 525 feet for the Graneros, 20 to 25 feet for the Greenhorn, and about 125 feet for the Carlile, or from 350 to 640 feet for the entire Benton group.

The Niobrara limestone is one of the formations which outcrops in the foothills and is the highest and easternmost one that contributes essentially to the typical foothills topography. It consequently outcrops as a long, narrow belt parallel to the mountains and to the other ridges of the foothills. The position of this belt is in general from 2 to 3 miles east of the mountains, approaching nearer to them or extending farther out toward the plains, according as the dip is steep or gentle. The basal member of the Niobrara usually consists of thick and massive limestone and makes a very distinct ridge, but where this member is thinner or less massive the ridge disappears. The dip is in general noticeably steeper in the basal bed, which lies nearest the mountains, and flattens perceptibly toward the east. The width of this belt is between one-eighth and one-half mile, varying with the amount of dip, as the thickness of the formation remains fairly constant.

The Niobrara is essentially a limestone formation, although calcareous shales make up a considerable part of it. The thickness is about 400 feet. The basal member is a massive white to gray limestone whose thickness ranges from 10 to 20 feet. This bed, which rests with apparent conformity on the top member of the Benton (Carlile shale), is apparently persistent, having been seen through practically the entire length of the region studied. It is succeeded by shaly limestones and calcareous shales, the former predominating

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and the calcareous nature of all the beds being persistent. These beds vary somewhat in character along the strike, fairly massive limestones being developed at several places. These more massive limestone beds are apparently present at several horizons but predominate toward the middle of the formation.

The Niobrara is overlain by the Pierre shale, which differs from it most noticeably in being noncalcareous. Several sandstones are present, the most characteristic being the Hygiene sandstone member, which occurs at about 1,000 feet above the base of the Pierre. Most of these sandstones are somewhat local in extent and their exact stratigraphic position has not been determined. A few thin calcareous beds are also present. The thickness of the Pierre shale probably exceeds 5,000 feet.

The Fox Hills formation consists of shales and sandstones, with a few thin beds of limestone. The formation is characteristically shaly in its lower part and characteristically sandy in its upper part, the top bed being a very persistent and easily recognized greenish sandstone about 40 feet thick. The thickness of the Fox Hills is apparently about 1,300 feet.

The Laramie formation, which rests with apparent conformity on the Fox Hills, consists of sandstones, shales, and coal beds. The entire thickness of the formation is probably about 1,000 feet.

South of the region here described, in the vicinity of Denver, the Laramie formation is succeeded unconformably by the Arapahoe and Denver formations, neither of which outcrop within this area. Both the Arapahoe and the Denver are probably of Tertiary age. Still younger Tertiary beds occur both south of Denver, where they rest on the Denver formation, and north of Greeley, where they overlie the Laramie. These, also, are entirely absent in the region here described.

The youngest beds of this region consist of the gravels that cap the mesas and the sands and gravels that lie along the flood plains of the streams.

Of all these formations the Niobrara alone is calcareous enough to be considered a possible important source of cement material, although thin and local limestones are present in the red beds and in the Morrison. These thin beds, however, have not been investigated for the purpose of this report.

REQUIREMENTS FOR CEMENT MATERIALS.

Portland cement, according to Eckel,[a] is "an artificial product, obtained by finely pulverizing the clinker produced by burning to semifusion an intimate mixture of finely ground calcareous and argillaceous material, this mixture consisting, approximately, of

[a] Eckel, E. C., Bull. U. S. Geol. Survey No. 243, 1905, p. 23.

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one part of silica and alumina to three parts of carbonate of lime (or an equivalent amount of lime)."

The mixture of calcareous and argillaceous material required for the manufacture of cement can be obtained from a variety of raw materials by mixing in the proper proportion. The essential requirement is that the mixture when ready for burning shall contain about 75 per cent of lime carbonate ($CaCO_3$) and 20 per cent of silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) together, the remaining 5 per cent including magnesium carbonate, sulphur, and alkalies. It is essentially important that the proportion of magnesia and sulphur should be small. It is furthermore important that the alumina and iron oxide should be less than half the amount of silica and preferably that they should be about one-third of the silica. This requirement is usually expressed as follows:

$$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} > 2 < 3.5$$

If a single rock, such as argillaceous limestone or calcareous shale, contains within itself the percentage of lime prescribed above, with the remaining constituents (silica, alumina, and iron) in the proper ratio, it could evidently be used for cement manufacture without the addition of any other material. The nearer that any rock comes to this composition the less the amount of other material that will have to be added to produce the required mixture. The customary practice in the Pennsylvania and New Jersey cement districts is to use an argillaceous limestone, or so-called "cement rock," with an admixture of a relatively small amount of purer limestone. There are, according to Eckel,[a] obvious advantages in using such a combination of materials. As a larger part of the mixture is made up of a single rock, the grinding does not have to be as fine as if two rocks of entirely different composition were to be mixed together, and probably also less fuel is required when the bulk of the material is derived from a single rock.

It is also essential that these materials should occur in large quantities and in such a position that they can be cheaply quarried. The cement business is essentially a manufacturing industry, and good materials are present in abundance at so many places that they have little intrinsic value unless the localities at which they occur are so situated that the processes of quarrying and manufacturing can be carried on at low cost.

[a] Op. cit., p. 31.

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DESCRIPTION OF LOCAL MATERIALS.

NIOBRARA LIMESTONE.

The following sections of the Niobrara limestone were measured at scattered localities along the outcrop from Laporte (which is about 4 miles northwest of Fort Collins) on the north to a point about 8 miles west of Longmont on the south, the length of the belt thus studied being about 35 miles. These localities are shown in figure 26. Their selection was governed entirely by the occurrence of good natural outcrops. Most of them are situated near points where large streams break through the ridges of the foothills, and are consequently well located with reference to possible industrial development, being on lines of naturally easy transportation. The sections consist of measurements partly of the basal bed of the Niobrara, which is a massive and relatively pure limestone, and partly of less massive and more argillaceous limestones interbedded with calcareous shales that occur somewhat higher in the formation. It is not known whether all of the latter represent the same horizon or whether two or more horizons are represented.

Section in road cut one-half mile north of Laporte (one-third mile south by one-fourth mile west of northeast corner sec. 29, T. 8 N., R. 69 W.).

	Feet.
Limestone,[a] thin bedded and somewhat shaly	18

Strike N. 12° E.; dip 24° SE.

Section at mouth of Dixon Canyon, 3 miles west by 2 miles south of Fort Collins (one-tenth mile north by one-fourth mile west of southeast corner sec. 20, T. 7 N., R. 69 W.).

	Ft.	in.
Limestone,[b] thin bedded and with much shale	49	
Gray shale, with thin limestone beds	90	
Limestone [c]	1	5
Shale [c]		8
Limestone [c]	1	3
Shale [c]		5
Limestone [c]	1	5
Shale [c]		6
Limestone [c]	11	2
Sandstone, gray, brownish.		

Strike N. 4° W.; dip 24° NE.

Section in road cut 3 miles west of Loveland (one-third mile east of southwest corner sec. 9, T. 5 N., R. 69 W.).

	Feet.
Limestone,[d] thin bedded, shaly	43

Strike N. 3° E.; dip 25° SE.

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[a] Included in sample 165, p. 324.
[b] Included in sample 167, p. 324.
[c] Included in sample 166, p. 324.
[d] Included in sample 168, p. 324.

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Section in north bank of Dry Creek, 5 miles west by one-half mile north of Berthoud (two-fifths mile south by 2½ miles west of northeast corner sec. 13, T. 4 N., R. 70 W.).

	Feet.	In.
Limestone,[a] massive, white	19	4

Strike N. 11° W.; dip 44° NE.

Section on north bank of Little Thompson River, 5 miles west by 6½ miles north of Longmont (one-half mile west of southeast corner sec. 35, T. 4 N., R. 70 W.).

	Feet.
Shale, yellow, sandy (Pierre).	
Shale,[b] black	50
Limestone and black shale,[b] latter predominating toward top	22
Limestone,[b] black, shaly, with *Ostrea congesta*	40±
Concealed	30±
Limestone,[b] black, shaly	18
Concealed	200±
Limestone,[c] massive, white	14

Strike N. 3° E.; dip 20° SE.

Section at east base of Rabbit Mountain, near northeast corner sec. 14, T. 3 N., R. 70 W.

	Feet.
Calcareous shales or shaly limestone, weathering white	66
Shales as below but with less regular bedding and probably more calcareous	100
Dark shales with slaty bedding	98
Concealed, probably limestone	30
Massive limestone	15

Strike N.; dip 70° E.

Section in ditch one-third mile west of northeast corner sec. 21, T. 3 N., R. 70 W.

	Feet.
Limestone,[d] massive, white	15½

Section 7 miles west by 2 miles north of Longmont (one-third mile south by one-fourth mile west of northeast corner sec. 28, T. 3 N., R. 70 W.).

	Feet.
Limestone,[e] black, shaly	30

The above section constitutes the upper 30 feet of a bluff 40 feet high. The lower part of the bluff is concealed by talus. The beds lie almost flat.

Section 7¼ miles west by 2¼ miles north of Longmont (one-fifth mile south by one-fifth mile east of northwest corner sec. 28, T. 3 N., R. 70 W.).

	Feet.
Limestone,[f] massive, white	10

This is the basal ledge of the Niobrara and is exposed on the crest of a hill, just above a ditch. Gritty Benton shales are exposed below. The overlying beds are stripped off.

[a] Included in sample 169, p. 324.
[b] Included in sample 164, p. 324.
[c] Included in sample 163, p. 324.
[d] Included in sample 162, p. 324.
[e] Included in sample 161, p. 324.
[f] Included in sample 160, p. 324.

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Section in road bank 7 miles west by 1¼ miles north of Longmont (one-half mile west by one-fourth mile north of southeast corner sec. 28, T. 3 N., R. 70 W.).

	Feet.
Limestone,[a] black, shaly	20

Dip about 5° E.

Section in bank of Lykins Gulch, 8 miles west of Longmont (one-third mile west by one-fourth mile south of northeast corner sec. 5, T. 2 N., R. 70 W.).

	Feet.
Limestone,[b] argillaceous, with many thin shale beds	30

Dip 30° SE.

This section is about 100 feet below the top of the Niobrara.

Section in south bank of Lykins Gulch, 8 miles west of Longmont (one-half mile west by one-fourth mile south of northeast corner sec. 5, T. 2 N., R. 70 W.).

	Feet.
Limestone,[c] massive	15

Strike N. 44° E.; dip 28° SE.

The Niobrara limestone has already been described as occurring in a narrow north-south belt along a line of low ridges just east of the main foothills. It dips eastward under the plains at angles of 24° to 70° along the western edge. Most of these dips are so steep that within short distances they carry the limestone too deep to be quarried cheaply; consequently it is only where the limestone rises into a ridge of considerable height that there is any large amount of material that can be easily quarried. The most desirable localities for quarries are where the ridge is high but falls off steeply into a transverse valley, thus affording sites where quarries can be opened with their faces above the general drainage level and with a considerable bulk of rock near at hand. Such points exist where the limestone belt crosses the valleys of St. Vrain Creek, Little Thompson Creek, Thompson River, and Cache la Poudre River. At each of these points, except on Little Thompson Creek, a railroad follows the line of the stream and crosses the limestone belt, the topographic conditions favorable for a good quarry site being thus combined with easy transportation facilities. There are numerous localities on either side of these railroads where quarries could be opened.

OTHER SOURCES OF CEMENT MATERIAL.

The following section represents a shale bed in the Pierre, a short distance above the top of the Niobrara.

Section 8 miles west of Longmont (one-fourth mile west by one-fourth mile south of northeast corner sec. 5, T. 2 N., R. 70 W.).

	Feet.
Black clay shale[d]	50

[a] Upper 12 feet included in sample 169, p. 324.
[b] Included in sample 157, p. 324.
[c] Included in sample 156, p. 324.
[d] Included in sample 158, p. 324.

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No other sections in the Pierre or other formations above or below the Niobrara were measured, but the Pierre contains a large amount of shale, much of which would doubtless be suitable for cement manufacture if it were required. Other limestones have also been mentioned above as being present in the lower formations, and some of these possibly occur at such points and with such thickness that they would be available as cement material.

Another source of possible cement material is the waste lime of the local sugar factories. These factories, which are situated at Longmont, Loveland, Fort Collins, Greeley, and other points, use a large amount of limestone in refining sugar. The processes require that this limestone shall be very pure, and it is said that of themselves they add nothing that is objectionable from the cement manufacturer's standpoint. The waste lime consists of a very fine chemical precipitate, composed essentially of carbonate of lime, with a considerable amount of organic matter and moisture. The composition of this material as it comes from the presses is shown in analysis 170, on page 325. This material has no present value, and is washed out of the sugar factory by running water and dumped on ground that has to be purchased for this purpose. Analysis No. 171, on page 325, shows the composition of material from the dump near Longmont, which had probably been lying there for about eighteen months.

A very large amount of this material has accumulated around the sugar factories, and it is increasing at the rate of about 9,000 tons a year for each of the larger factories, or a total of 57,000 tons a year for the factories of the entire district.

ANALYSES.

The analyses given in Tables 1 and 2 represent samples that were taken especially for the purpose of this report. Table 1 represents the basal bed of the Niobrara limestone and Table 2 represents the more argillaceous beds above the base. The localities of these samples agree with those of the sections given on pages 320–322, and the sections show just what beds are represented in each sample. Most of these samples were taken by chipping off small pieces of the rock across the entire face of the bed as exposed in a good natural outcrop, and consequently represent the average composition of the entire bed.

In obtaining samples 157, 161, 164, and 168, however, small representative pieces were broken off at intervals of a few inches across the entire bed. It is probable that these also represent the average composition of the whole bed at the points where they were taken.

Table 3 represents a sample of new waste lime from a sugar factory at Longmont and another of older lime from the dump of the same

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factory. All these analyses were made at the laboratory of the United States Geological Survey at St. Louis, Mo., by P. H. Bates, A. J. Phillips, and G. R. Brobst, full credit, according to the division of the work, being given in the tables.

TABLE 1.—*Analyses of basal bed of Niobrara limestone.*

	166.	169.	163.	162.	160.	156.
Silica	[a] 5.97	[a] 7.14	[b] 5.33	[a] 5.35	[a] 5.10	[a] 4.79
Alumina	[a] 1.74	[a] 1.63	[b] 1.54	[a] 1.45	[a] 1.80	[a] .99
Ferric oxide	[a] .18	[a] .14	[b] .23	[a] .45	[a] .03	[a] .14
Ferrous oxide	[a] .64	[a] .48	[b] .48	[a] .56	[a] .56	[a] .48
Lime	[a] 49.82	[a] 49.11	[b] 50.69	[a] 51.29	[a] 50.27	[a] 50.54
Magnesia	[a] .75	[a] 1.04	[b] .56	[a] .57	[a] 1.01	[a] .56
Sulphuric anhydride [b]	Trace.	Trace.	.....	.09	.12	.10
Soda	[a] .16	[a] .17	[b] .05	[a] .03	[a] .07	[a] .14
Potassa	[a] .34	[a] .45	[b] .21	[a] .13	[a] .26	[a] .37
Water at 100° C. [b]	.17	.33	.12	.08	.17	.17
Water above 100° C. [c]	.07	.19	.51	.24	.49	.29
Carbon dioxide [c]	39.84	39.00	39.90	40.07	40.11	40.38
Organic [c]	.43	.52	.44	.27	.16	1.09
Total	100.11	100.20	100.06	100.58	100.16	100.04

[a] Determined by A. J. Phillips. [b] Determined by G. R. Brobst. [c] Determined by P. H. Bates.

166. One-eighth mile north by one-third mile west of southeast corner sec. 20, T. 7 N., R. 69 W., Larimer County.
169. Two-fifths mile south by two-fifths mile west of northeast corner sec. 13, T. 4 N., R. 70 W., Larimer County.
163. Two-fifths mile east of southwest corner sec. 35, T. 4 N., R. 70 W., Larimer County.
162. One-third mile west by 100 feet south of northeast corner sec. 21, T. 3 N., R. 70 W., Boulder County.
160. One-fifth mile south by one-fifth mile east of northwest corner sec. 28, T. 3 N., R. 70 W., Boulder County.
156. One-half mile west by one-fourth mile south of northeast corner sec. 5, T. 2 N., R. 70 W., Boulder County.

TABLE 2.—*Analyses of shaly members of Niobrara limestone.*

	165.	167.	168.	164.	161.	159.	157.	158.
Silica [a]	17.40	11.10	11.13	18.59	9.60	25.54	15.34	60.31
Alumina [a]	6.17	3.51	4.58	6.03	2.41	8.72	5.34	16.61
Ferric oxide [a]	.54	.18	.40	.31	.18	.54	.54	2.33
Ferrous oxide [a]	.56	.81	.56	.89	.81	.80	1.13	1.70
Lime [a]	39.38	43.86	43.60	38.55	45.87	33.70	40.81	2.91
Magnesia [a]	.67	.99	1.05	.70	.81	.56	.80	2.46
Sulphuric anhydride [b]	.52	.07	Trace.	.10	.32	.14	.12	.12
Soda [a]	.18	.11	.20	.24	.19	.12	.29	.99
Potassa [a]	.62	.61	.78	.98	.69	.47	.93	2.95
Water at 100° C. [b]	.86	.60	.57	.67	.41	.66	.48	1.15
Water above 100° C. [c]	1.98	2.01	1.21	2.13	1.43	2.38	1.61	4.52
Carbon dioxide [c]	30.75	34.58	34.38	29.14	36.00	25.43	32.15	2.81
Organic [c]	.36	1.64	1.72	1.78	1.48	1.19	.67	1.34
	99.99	100.07	100.18	100.11	100.20	100.25	100.21	100.20

[a] Determined by A. J. Phillips. [b] Determined by G. R. Brobst. [c] Determined by P. H. Bates.

165. Shaly limestone, one-third mile south by one-fourth mile west of northeast corner sec. 29, T. 8 N., R. 69 W., Larimer County.
167. Shaly limestone, one-tenth mile north by one-fourth mile west of southeast corner sec. 20, T. 7 N. R. 69 W., Larimer County.
168. One-third mile east of southwest corner sec. 9, T. 5 N., R. 69 W., Larimer County.
164. Shaly limestone, one-third mile west of southeast corner sec. 35, T. 4 N., R. 70 W., Larimer County.
161. Shaly limestone, one-third mile south by one-fourth mile west of northeast corner sec. 28, T. 3 N., R. 70 W., Boulder County.
159. Shaly limestone, one-half mile west by one-fourth mile north of southeast corner sec. 28, T. 3 N., R. 70 W., Boulder County.
157. Shaly limestone, one-third mile west by one-fourth mile south of northeast corner sec. 5, T. 2 N., R. 70 W., Boulder County.
158. Clay shale, one-fourth mile west by one-fourth mile south of northeast corner sec. 5, T. 2 N., R. 70 W., Boulder County.

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TABLE 3.—*Analyses of waste lime from sugar factory at Longmont.*

[Material dried at 105° C.]

	New lime (170).	Old lime (171).
Silica [a]	1.73	2.26
Alumina [a]	.95	1.22
Ferric oxide [a]	.31	.40
Lime [a]	48.91	48.17
Magnesia [a]	1.91	2.26
Sulphuric anhydride [b]	1.32	2.26
Soda [a]	.44	.07
Potassa [a]	.24	.06
Water above 100° C. [c]	3.43	2.62
Carbon dioxide [a]	30.38	35.56
Organic [c]	10.13	5.46
	99.75	100.34
Moisture at 105° C.	53.12	28.76

[a] Determined by P. H. Bates.
[b] Determined by G. R. Brobst.
[c] Owing to lack of facilities the results for combined H_2O and organic matter are approximated but their total is accurate.

NOTE.—FeO can not be determined in the presence of so large an amount of soluble organic matter.

The analyses given in Table 4 represent the composition of Niobrara limestone and of an older limestone west of Denver.

TABLE 4.—*Analyses of limestones west of Denver.*

[L. G. Eakins, analyst.]

	1.	2.
Lime (CaO)	48.73	27.49
Magnesia (MgO)	2.95	18.03
Manganese (MnO)	.49	.20
Alumina (Al_2O_3)	.53	.54
Iron oxide (Fe_2O_3)	.38	.11
Phosphoric acid (P_2O_5)	.032	.029
Water (H_2O)	.11	.61
Carbonic acid (CO_2)	41.71	41.40
Insoluble	5.32	12.01
	100.252	100.419

1. "Upper Wyoming" limestone, Morrison, Colo. Mon. U. S. Geol. Survey, vol. 27, 1896, p. 55.
2. Niobrara limestone west of Denver, Colo. Mon. U. S. Geol. Survey, vol. 27, 1896, p. 67.

The following analyses, taken from a report by N. M. Fenneman,[a] show the composition of the Pierre shale near Boulder. Fenneman says:

A partial analysis of the shale from the Austin yard, made by Prof. C. S. Palmer, is given by Mr. Austin, as follows:

Analysis of shale from Austin yard, Boulder.

SiO_2	60.0
Al_2O_3	18.0
Fe_2O_3	4.75
MgO	2.0

[a] Geology of the Boulder district, Colorado: Bull. U. S. Geol. Survey No. 265, 1905, pp. 73, 74.

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An analysis of a single selected lump (not a mixed sample) of the shale from Mr. Lee's yard, made by Mr. W. B. Stoddard, of Boulder, and furnished by Mr. Lee, is as follows:

Analysis of shale from Lee yard, Boulder.

SiO_2	63.309
Al_2O_3	14.380
Fe_2O_3	6.270
FeO	.859
CaO	1.810
MgO	2.570
Na_2O	2.190
K_2O	1.280
Loss by drying	2.053
Loss by ignition	5.223
	99.944

CONCLUSIONS.

It can readily be seen that the analyses in Tables 1 and 2 represent beds eminently suitable for cement manufacture, most of them being especially low in magnesia and some individually approaching the theoretical composition of a correct cement mixture. There consequently seems to be little doubt that at many points along the outcrop of the Niobrara within the area shown on the map materials suitable in composition for cement manufacture can be obtained.

The possible utilization of these materials does not, however, depend entirely on the composition of the local beds. Other factors of at least equal importance are the problem of procuring quarry sites where large quantities of rock of uniform composition can be cheaply quarried, the local cost of manufacture, the extent of the available market, and the freight rates to and the competition with other cement materials in that market.

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CEMENT MATERIAL NEAR HAVRE, MONT.

By LEON J. PEPPERBERG.

INTRODUCTION.

In the vicinity of Havre, Mont., there are deposits of limestone and shale which contain the constituent materials of Portland cement. The occurrence of rock suitable for the manufacture of such cement is of considerable local importance owing to the fact that other building materials, such as stone and timber, are scarce in this region. During the summer of 1908, while engaged in an investigation of the Milk River coal field, the writer found opportunity to examine these rocks. Previous examination has been made by engineers and chemists, but no detailed statement concerning their character or extent has been published.

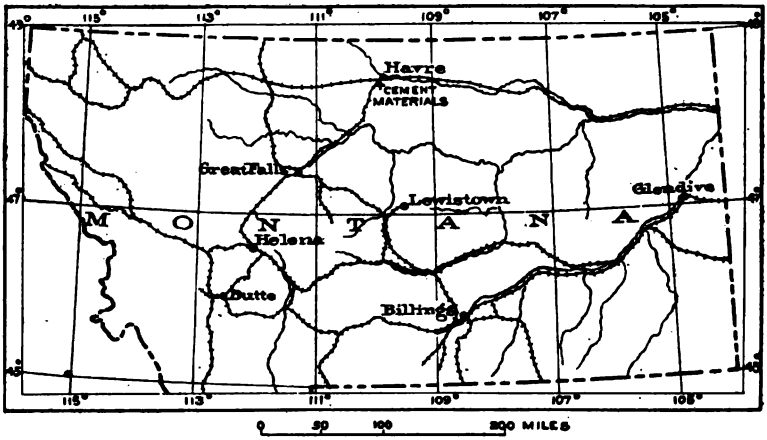

FIGURE 27.—Sketch map of Montana, showing location of cement materials near Havre.

The writer is indebted to Mr. S. S. Voorhees, of the United States Geological Survey, for valuable suggestions in connection with the preparation of this paper; to Mr. F. H. Newell, Director of the United States Reclamation Service, who furnished a number of chemical analyses; and to Mr. E. C. Eckel, whose friendly interest and suggestions have been of great value and assistance.

LOCATION AND EXTENT.

The cement materials described in this paper are located in the NW. ¼ sec. 31, T. 32 N., R. 16 E., and the NE. ¼ sec. 36, T. 32 N., R. 15 E. of the principal meridian, Montana, about 5 miles south and a little west of Havre, a division point on the Great Northern Railway.

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(See fig. 27.) The outcrop occurs in a group of low hills, composed largely of igneous rock, which stand out prominently in comparison with the surrounding flat, treeless plains. The area underlain by the cement-making materials is about 80 acres.

GEOLOGY.

The sedimentary rocks exposed in this district belong to the Montana group of Upper Cretaceous age (with the exception of the cement material which will be discussed later), and consist of the Judith River formation and the overlying Bearpaw shale.

JUDITH RIVER FORMATION.

The Judith River formation, which is composed mainly of alternating layers of light-colored sandstone and shale, is coal bearing in this district, and on account of the relation of fuel to the manufacture of cement deserves brief mention. It outcrops extensively along Milk River north and west of Havre, where it weathers into typical badland forms. It is also exposed along the coulées close to the limestone deposit. Subbituminous ("black lignite") coal beds of workable thickness occur within the upper 150 feet of this formation.

BEARPAW SHALE.

The Bearpaw shale overlies the Judith River conformably, and consists of dark leaden-gray argillaceous shale containing large concretions, many of which are highly fossiliferous, and intercalated thin beds of sandstone. Selenite (gypsum) crystals or flakes are scattered throughout the formation. The Bearpaw shale outcrops about 1 mile east of the limestone described below, near a coal prospect, and along Milk River north and west of Havre. This shale could be used as a source of alumina and silica in the manufacture of Portland cement if future development should show that the limestone is too high in lime to be used as a natural cement material.

LIMESTONE, SHALE, AND IGNEOUS ROCK.

The principal cement materials of the district are highly metamorphosed limestone and shale. These are surrounded by igneous rock and as they are closely associated they will be treated together. The igneous rock is unimportant economically save for the effect it has had on the limestone and shale. It was found by Albert Johannsen, on examination of a thin section from the rock in contact with the limestone, to be a monzonite porphyry.

The limestone and shale are inclosed in the intruded igneous rock. As no fossils were found in these beds their geologic age is unknown. The writer is of the opinion that they were broken off the original

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mass at great depth and floated to their present position by the intrusive rocks with which they are associated. Several openings that have been made along the outcrop of the limestone afforded good opportunity to measure its thickness and to collect fresh samples. These openings are insufficient, however, to determine the amount of shale present, although it is probably large. The amount could be ascertained by crosscutting and drilling.

The limestone bed has a thickness of 15 to 20 feet and the dip of the strata at the outcrop is about 30° S. 10° W. There are two distinct varieties. One is a hard, compact, highly crystalline, heavy white limestone, having a greenish tinge. Its original joint and bedding planes have been almost destroyed by metamorphism. This variety will be referred to later as the white limestone. The other variety, a minutely banded, grayish limestone, although highly crystalline, is less compact than the white limestone and shows some leaching by water. The dark bands which follow the original bedding planes of this rock are due to impurities that probably consist largely of carbonaceous matter, for when highly heated the dark color disappears. In dilute hydrochloric acid the rock effervesces freely, and after the carbonate of lime is completely dissolved a dark sediment of carbonaceous matter and clay remains. This variety will be referred to later as gray limestone. Thin sections of both varieties were examined by Mr. Johannsen, who reported as follows:

The two thin sections of limestone examined consist largely of calcite. There is a very small amount of opal and opacite, which fills cracks and forms the isotropic material. Throughout the rock occur extremely minute crystals of an indeterminable mineral, which may be a calcium pyroxene or amphibole. In a few places there are radial bunches of crystals; also too small to determine microscopically, which may likewise be a calcium pyroxene or amphibole. Some garnet occurs.

COMPOSITION OF CEMENT MATERIALS.

The following ten analyses represent samples of cement materials collected from the deposits described above.

Analyses of cement materials near Havre, Mont.

	1.	2.	3.	4.	5.	6.
Silica (SiO_2)	12.83	20.60	18.86	14.50	16.00	67.78
Alumina (Al_2O_3)	3.10	10.67	3.68	2.74	9.80	18.95
Ferric oxide (Fe_2O_3)			3.18	7.22		2.67
Manganese oxide (MnO)						.50
Lime (CaO)	50.65	44.66	49.38	44.83	45.96	.73
Magnesia (MgO)	.93	2.22	.73	2.02	2.08	1.24
Sulphuric anhydride (SO_3)			.25			.06
Alkalies (Soda (Na_2O)						2.23
Alkalies (Potassa (K_2O)						.43
Water at 100° C.						1.30
Carbon dioxide (CO_2)	28.60	22.27	22.05	27.35		
Ignition loss			1.45		25.00	1.92
	96.11	100.42	99.58	98.66	98.84	99.81

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Analyses of cement materials near Havre, Mont.—Continued.

	7.	8.	9.	10.
Silica (SiO_2)	13.98	19.80	10.70	18.20
Alumina (Al_2O_3)	4.21	6.20	4.70	8.60
Ferric oxide (Fe_2O_3)	1.35	.90	.30	1.30
Manganese oxide (MnO)	.....	.10	Trace.	Trace.
Calcium carbonate ($CaCO_3$)	73.93	69.70	80.90	67.75
Magnesium carbonate ($MgCO_3$)	.65	.80	1.20	1.50
Potassa and soda (K_2O, Na_2O)	.....	1.70	1.10	2.10
Sulphuric anhydride (SO_3)	.....	.30	.80	.....
Barium oxide (BaO)	.....	Trace.	Trace.	Trace.
Moisture	.....	.50	.20	.30
	94.12	100.00	99.90	99.75

1. Gray limestone, analyzed by R. G. Brobst, United States Geological Survey, structural-materials laboratories. Carbon dioxide determined by J. D. Davis, United States Geological Survey, technologic branch.
2. White limestone, analyzed by R. G. Brobst, United States Geological Survey, structural-materials laboratories. Carbon dioxide determined by Chase Palmer, United States Geological Survey.
3. Limestone, analyzed by Ricketts & Banks.
4. Limestone, analyzed by Prof. A. H. Phillips, Princeton University.
5. Limestone, analyzed by W. H. Andrews, chemist and superintendent Union Portland Cement Company, Rushsylvania, Ohio.
6. Shale, analyzed for United States Reclamation Service at United States Geological Survey structural-materials laboratories.
7. Limestone, analyzed by H. J. Detweiler, Allentown, Pa.
8, 9, 10. Limestone, analyzed by Paul Reisinger.

Analyses 1 and 2 represent samples collected by the writer; Nos. 3 to 10, inclusive, are taken from a report on the examination of deposits of clay and limestone in the vicinity of Havre, submitted by Charles P. Williams, of Great Falls, Mont., to H. N. Savage, supervising engineer, United States Reclamation Service, Billings, Mont. No. 6 is an analysis of shale occurring near the limestone deposit, which can be used to mix with the limestone should it be found to be too high in lime. Nos. 7 to 10 are of value only in striking an average (with the other five analyses of limestone) of the constituents other than lime and magnesia. Neither carbon dioxide nor ignition loss were determined in these four analyses and the total lime and magnesia are figured as carbonates. It will be shown below that the amount of carbon dioxide present is not sufficient to form carbonates of all the lime and magnesia in the rock. Therefore, the figures for these two constituents in analyses 7 to 10 have been disregarded in determining the average composition of the limestone.

A study of analyses 1 to 5, inclusive, with the assumption that the ignition loss in No. 5 is carbon dioxide, shows that the amount of carbon dioxide present is not sufficient to form calcium carbonate of all the lime contained in the rock. Therefore the excess lime must be combined chemically with some other elements. As stated above, Mr. Johannsen believes the rock to contain calcium pyroxene or amphibole, and on this basis two sets of calculations were made, the calcium silicate being assumed in one to be tremolite and in the other to be wollastonite. It was found from these calculations that the

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excess lime is probably combined with silica to form wollastonite ($CaSiO_3$), and the following table is based on this hypothesis.

Probable chemical combination of carbon dioxide, magnesium, calcium, and silica, in samples 1 to 5, the calcium silicate being assumed to be wollastonite and the other constituents not being considered.

	1.	2.	3.	4.	5.
Magnesium carbonate ($MgCO_3$)	1.93	4.64	1.52	4.22	4.35
Calcium carbonate ($CaCO_3$)	62.70	45.11	48.31	57.15	51.66
Wollastonite ($CaSiO_3$)	24.91	39.73	36.37	26.64	30.85
Lime (CaO)	3.47	.27	4.82	.....	2.18
Alumina (Al_2O_3)	3.10	10.67	3.68	2.74	9.80
Ferric oxide (Fe_2O_3)			3.18	7.22	
Silica (SiO_2)	.....	.....	.....	.69	.....
Sulphuric anhydride (SO_3)	.....	.....	.25	.....	.....
Ignition loss	.....	.....	1.45	.....	.....
	96.11	100.42	99.58	98.66	98.84

In the above table all of the magnesia (MgO) is figured as magnesium carbonate ($MgCO_3$). The remaining carbon dioxide (CO_2) is combined with lime (CaO) to form calcium carbonate ($CaCO_3$) and the remaining lime is combined with the available silica (SiO_2) to form wollastonite ($CaSiO_3$). In Nos. 1, 2, 3, and 5 a small percentage of the lime is uncombined with either carbon dioxide or silica. The excess lime may be combined with other elements present, or there may be inaccuracies in the chemical analyses. The presence of a calcium silicate was not suspected when the analyses were requested. Consequently the analyses were made simply to determine the fitness of the limestone for cement manufacture, and preliminary examinations of this kind do not require the exactness necessary for accurate chemical computations.

In the analyses, as calculated above, from 25.26 to 35.1 per cent of the lime is combined with carbon dioxide to form calcium carbonate, and from 12.13 to 19.13 per cent of the lime is combined with silica to form wollastonite.

The following table shows the average of nine analyses of limestone from the Havre district:

Average of nine analyses of limestone collected near Havre, Mont.

Silica (SiO_2)	16.16
Alumina (Al_2O_3)	7.55
Ferric oxide (Fe_2O_3)	
Manganese oxide (MnO)	.10
Lime (CaO)	47.09
Magnesia (MgO)	1.59
Sulphuric anhydride (SO_3)	.45
Alkalies: Soda (Na_2O) and potassa (K_2O)	1.63
Carbon dioxide (CO_2)	25.05
Moisture	.61
	100.23

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The following table shows the chemical combination of carbon dioxide, magnesia, lime, and silica, on the assumption that the calcium silicate is wollastonite, computed from the average of nine analyses given above:

Composition of wollastonite limestone calculated from the average of nine analyses of limestone collected near Havre, Mont.

Magnesium carbonate ($MgCO_3$)	3.35
Calcium carbonate ($CaCO_3$)	52.93
Wollastonite ($CaSiO_3$)	31.16
Lime (CaO)	2.45
Alumina (Al_2O_3) and Ferric oxide (Fe_2O_3)	7.55
Manganese oxide (MnO)	.10
Sulphuric anhydride (SO_3)	.45
Alkalies: Soda (Na_2O) and potassa (K_2O)	1.63
Moisture	.61
	100.23

CONTROL OF THE MIX.

The formulæ for determining the "cementation index" proposed by Eckel,[a] when applied to the analysis of the gray limestone (No. 1) and the white limestone (No. 2), give the following results: The gray has a cementation index of 0.73, which shows this variety to be high in lime, and the white limestone has a cementation index of 1.40, indicating that it is low in lime. From these figures it is evident that a Portland cement can be made from a mixture of the two limestones without the addition of clay or shale.

When Eckel's formula for proportioning mixture[b] is applied to the two limestones the resulting figures show that 1.29 parts of the gray limestone should be used for each part of white limestone, by weight, to give the proper percentage of silica, lime, magnesia, and alumina and iron oxide. On this basis S. S. Voorhees and the writer conducted the following experiments: Samples of both the gray and the white limestone were ground so as to pass through a 120-mesh sieve and mixed in the proportion of 1.29 to 1, as just stated. This mixture was subjected to the heat of a blast lamp, the result being a dark clinker having a bluish tinge. The clinker was ground to flour and one-half gram treated with dilute hydrochloric acid, which dissolved all but a small trace of the cement, showing that all of the free silica had been combined with the lime. Five grams of the cement were mixed into a pat with 1 cubic centimeter of water. Although the cement was imperfectly calcined the initial set took place in three hours and the final set in eight hours, showing that the material was a normal Portland cement.

[a] Eckel, E. C., Cements, limes, and plasters, 1905, p. 391.

[b] Idem, pp. 392–393.

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AMOUNT OF AVAILABLE LIMESTONE.

Eckel[a] states that—

> A Portland cement plant running on dry raw materials, such as a mixture of limestone and shale, will use approximately 20,000 tons of raw material per year per kiln. Of this about 15,000 tons are limestone and 5,000 tons shale. Assuming that the limestone weighs 160 pounds per cubic foot, which is a fair average weight, each kiln in the plant will require about 190,000 cubic feet of limestone per year. As the shale or clay may be assumed to contain considerable water, a cubic foot will probably contain not over 125 pounds of dry material, so that each kiln will also require about 80,000 cubic feet of shale or clay.
>
> A cement plant is an expensive undertaking, and it would be folly to locate one with less than twenty years' supply of raw material in sight. This would require that, to justify the erection of a cement plant on any property, for each kiln of the proposed plant there must be in sight at least 3,800,000 cubic feet of limestone and 1,600,000 cubic feet of clay or shale.

A close estimate can not be made of the total amount of limestone available near Havre because of the present meager knowledge of the extent of the beds. As previously stated, an area of about 80 acres is underlain by the limestone. This estimate is very conservative and drilling or extensive prospecting would probably disclose a greater amount of the rock. However, on the assumption that a 15-foot bed of limestone underlies 80 acres, 52,272,000 cubic feet, or, at 160 pounds to the cubic foot, about 4,181,260 tons of rock, would be available. On the further assumption that the 20,000 tons of raw material required per kiln per year will in this area consist entirely of limestone, the beds herein described contain enough raw material to run one kiln over two hundred years, or ten kilns twenty years. In addition there is undoubtedly sufficient shale in the immediate vicinity to meet the needs of a plant should it become necessary at any time to add shale to the mixture.

FUEL SUPPLY.

Almost one-half of the total cost of manufacturing cement is chargeable to the cost of fuel. On this account it is imperative that the fuel supply be close at hand if the cement is to be manufactured economically. As previously stated, the Judith River formation of this region is coal bearing. A small coal prospect is located about 1 mile east of the limestone deposit and coal is mined in large quantities north of Havre across Milk River and southeast of Havre.

The following table gives analyses of three samples of subbituminous coal that is available for the manufacture of cement in this district at a cost of about $2 per ton at the mine:

[a] Eckel, E. C., and Crider, A. F., Geology and cement resources of the Tombigbee River district, Mississippi-Alabama: Senate Doc. No. 165, 58th Cong., 3d sess., 1905.

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Analyses of coal from the Havre district.

[Made at the United States Geological Survey fuel-testing plant, Pittsburg, Pa.]

Laboratory No.	6479	6473	6478
Air-drying loss	15.50	16.30	22.90
Analysis of air-dried sample:			
Moisture	7.64	7.81	8.16
Volatile matter	28.17	35.02	34.59
Fixed carbon	51.95	41.35	48.51
Ash	12.24	15.82	8.74
	100.00	100.00	100.00
Sulphur	.71	.95	.87
Calorific value determined:			
Calories	5,400	5,243	5,646
British thermal units	9,720	9,437	10,163

Pulverized coal high in volatile matter and low in ash and sulphur is most commonly used in modern rotary-kiln practice. The above analyses show the coal to be high in volatile matter and low in sulphur. The ash varies according to the increase or decrease of thin bony layers in the bed. This coal would probably make good gas, or it could be powdered and blown into the kiln in the usual manner.

WATER.

In the arid regions of the West the relation of the location of a plant requiring the use of water to the water supply and the kind of water available are factors that must be considered. The water from most of the springs in the Havre district is alkaline and unfit for boiler use. About half a mile from the limestone is a spring that was tramped in by cattle at the time the writer made the examination. By sinking wells at this place a small supply of water could be obtained, but it would probably be alkaline and insufficient to supply the needs of a mill. If a mill is erected either at the quarry or at the junction of the railroads it will probably be necessary to pipe water from Milk River in order to insure both good quality and a quantity large enough to supply a mill having one or more kilns.

TRANSPORTATION FACILITIES.

The region between the limestone and the Great Northern Railway is practically a flat prairie, and a spur about 5 miles long could be constructed from Pacific Junction to the quarry at small expense, connecting with the main line as well as with the Great Falls branch (Montana Central division of the Great Northern Railway), thus giving transportation facilities east, south, and west to the Pacific coast and into Canada. From the above statement it is evident that the cement materials are within easy reach of what may seem to be good transportation facilities into a large territory. However, it should be

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borne in mind that much better freight rates could be obtained if two or more competing lines were located near the cement materials. The cost of transporting the finished product from the cement plant to market is one that should be carefully considered and investigated before erecting a plant.

MARKET AND COMPETITION.

In the Cement and Engineering News for August, 1908, an article headed "Pacific coast cement prices decline" states that the cement mills in Washington and California are capable of supplying the demands for the product along the western coast. These mills—

> have reduced the prices from 60 to 75 cents per barrel for cement, and the grades made in the Middle West are suffering as a result of the slashing by the extreme western concerns. These grades are sold at $2.50 to $2.75 per barrel, depending on their standing for reliability. Owing to their distance from market and the heavy freight, amounting to nearly $1.50 per barrel, against them, these eastern cements are not able to enter into a competition that means a cut below $2.25, and even that figure loses them money on a basis of 85 cents per barrel at the factory.
>
> California cement has dropped from $3.05 per barrel, March 1, 1907, and $2.55 in March, 1906, to $2.20 at present. Eastern and foreign cements have dropped from $3.25 in March, 1907, and $3 per barrel in March, 1906, to $2.50 to $2.75 for eastern and $2.75 for foreign at present.
>
> At an estimated average drop per barrel of 60 cents for all grades, Seattle is saving, on an estimated cement consumption of 400,000 barrels per annum, a total of approximately a quarter of a million dollars for cement alone.

From the above statement it will be seen that it would be necessary at Havre to produce a cement of high quality at comparatively low cost and to obtain low freight rates in order to enter the coastal market and compete with the local product.

The cement materials herein described are located in a thinly populated section, but a number of large reclamation projects are contemplated in this general region and could use some of the cement produced. Moreover, under present conditions much of the product could be marketed in the large cities in Montana, in the Black Hills of South Dakota, and in Idaho, Wyoming, North Dakota, Nebraska, and probably Canada.

CONCLUSIONS AND SUMMARY.

In the foregoing pages it has been shown that the limestone and shale near Havre, Mont., are suitable materials for the manufacture of Portland cement. It has been shown further that a large percentage of the calcium in the limestone is combined with silica (calcium pyroxene or amphibole), probably forming wollastonite. The existence of a large part of the total amount of available lime in combination with silica, from which carbon dioxide does not have to be driven off in calcining, is in favor of this rock as a cement material, for the clinker

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can probably be produced with less fuel than from limestones containing the same total percentage of lime as a carbonate. So far as the writer can ascertain, this is the first time that limestone in which a large proportion of the lime exists as a silicate has been proposed for the manufacture of cement.

Before erecting a plant to utilize this material it would be well to prospect in detail to ascertain whether the composition of the limestone remains uniform throughout the area, for if after erecting the plant it is found that the rock is not of uniform composition it would be almost impossible to control the mix for the kiln charge and the plant would be one more among the cement mill failures, already too numerous. In this day of the specialized promoter too much emphasis can not be laid on the fact that although the use of cement as a building material is steadily increasing, the erection of a plant near a supply of good cement material, with fuel close at hand, will not necessarily be a financial success.

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GANISTER IN BLAIR COUNTY, PENNSYLVANIA.

By CHARLES BUTTS.

INTRODUCTION.

One of the most important mineral industries of Blair County, Pa., is the exploitation of the rock known as ganister, which is used for refractory brick for various kinds of furnace linings. The name ganister is derived from the German ganster, meaning a spark, and owes its application to the fact that the rock will give a spark when struck with iron. In England the name is applied to siliceous beds underlying certain coal beds just above the Millstone grit, one bed of coal being known as the ganister bed. The name is also used for a mixture of ground quartz and clay that is used for refractory purposes and for road making.

NATURE OF THE BLAIR COUNTY GANISTER.

Chemically the ganister of Blair County and vicinity is a nearly pure silica rock, as shown by the subjoined analyses kindly furnished by Mr. J. D. Hartman, of Hollidaysburg, Pa.

Analyses of ganister from Canoe Mountain, Point View, Pa.

[Isaac Reese & Sons Company, Analyst.]

	1.	2.	3.	4.
Silica [SiO_2]	97.90	97.98	97.30	98.65
[Iron and alumina] (Fe_2O_3, Al [Al_2O_3])	.90	.95	1.20	.30
Lime [CaO]	.40	.25	.30	.25
Magnesia [MgO]	.36	.29	.30	.30
Loss on ignition	.40	.50	.85	.45
	99.96	99.97	99.95	99.95

Analyses of ganister from quarries at Point View, Pa.

	1.	2.	3.
[Silica] (SiO_2)	99.10	98.15	98.20
Fe and Al [Iron and alumina (Fe_2O_3, Al_2O_3)]	.60	1.20	1.35
Lime [CaO]	None.	None.	None.
Magnesia [MgO]	Trace.	Trace.	Trace.
Loss on ignition	.25	.20	.50

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Analysis of ganister from Pattonsville, Bedford County, Pa.

[E. F. Wood, Analyst.]

[Silica] (SiO_2)	98.00
Alumina [Al_2O_3]	1.10
Oxide of iron [Fe_2O_3]	.85
Combined water	.10

Analysis of ganister from Water Street Gap, Huntingdon County, Pa.

[S. A. Ford, Edgar Thompson Steel Works, Braddock, Pa., Analyst.]

[Silica] (SiO_2)	97.640
Oxide of iron [Fe_2O_3]	.652
Alumina [Al_2O_3]	.825
Lime [CaO]	.310
Magnesia [MgO]	.140
Loss on ignition	.460

The specific gravity of ganister ranges from 2.46 to 2.58. Physically ganister is to the naked eye a compact light-gray to white rock with a somewhat vitreous luster. It is more or less iron stained on the outside after exposure to the weather or to water along joint planes. Microscopic examination of a thin section shows the rock to have been made up originally of well-rounded quartz grains, 0.1 to 0.3 millimeter in diameter. These grains, however, have been enlarged by the addition of silica that is crystallographically continuous with the original grain, the boundaries of which are perfectly distinguishable. The addition of silica continued until the interstices between the original grains were filled and the rock was cemented into a compact mass. In other words, the rock, which was originally an ordinary pure quartz sandstone, has been changed to a quartzite. The difference between the quartzite, or ganister, and the sandstone is physical and not chemical.

GEOLOGIC OCCURRENCE AND RELATIONS.

The ganister rock of the region occurs as a bed or beds in the Medina formation of Silurian age. This formation extends through the mountain region of central Pennsylvania and makes the conspicuous ridges of which Tussey and Dunning mountains of Blair County are examples. It comprises two members—a lower red member, the "Red Medina," 400 to 600 feet thick, and an upper white member, the "White Medina," about 400 feet thick. The "White Medina" is overlain by the Clinton formation, which carries the red fossil iron ore of the region.

The "Red Medina" is composed of alternating layers of dark-red sandstone and shale; the "White Medina" consists, so far as exposed to view, of white sandstone and quartzite in layers 1 foot or more thick.

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The "White Medina" outcrops in a nearly vertical attitude along the crests of Tussey, Lock, Loop, Dunning, and other mountains. Indeed, the presence of this hard, resistant rock has been the condition of the formation of these ridges, the softer rocks on each side having been removed by erosion, leaving the hard sandstone standing up in bold relief. The original posture of these rocks was flat, and they have been tilted into their present attitude in the general folding to which the Appalachian Mountain belt has been subjected.

The ganister rock occurs as a bed or beds in the 400 feet, more or less, of the "White Medina" sandstone. Certain layers of the original sandstone have been permeated by water carrying silica in solution, and this silica has been deposited in crystalline form about the original grains, cementing them together into a compact mass. Just what position in the formation as a whole the ganister beds occupy or what proportion of it they comprise is not known, though the occurrence of the ganister on or near the crests of the ridges indicates that the position of some of the beds at least is near the middle of the formation. At McKee Gap a bed 18 to 40 feet thick was quarried for a time, and some rock has been taken from the outcrop on the crest of the mountain on the north side of the Juniata at Point View, where the thickness of rock quarried does not exceed 20 feet. The quality of the rock at McKee Gap is said to be of the very best.

METHODS OF EXPLOITATION AND LOCATION OF WORKINGS.

Practically all the ganister used at present is obtained in the form of bowlders, which constitute a thick mantle over the slopes of the Medina sandstone ridges of the region for 200 or 300 feet below their crests. This loose material has, of course, been derived from the sandstone strata outcropping along the crests of the ridges.

The rock is procured by laying an incline to or nearly to the crest of the ridge and then running tracks from the incline along the side of the ridge at vertical intervals of 40 or 50 feet. The material is rolled down the slope to the track next below and loaded into cars after having been broken to sizes suitable for handling. The cars are then let down the incline and dumped into railroad cars for shipment.

The ganister rock has been extensively worked in this way by J. D. Hartman and P. S. Duncan at McKee Gap, and is now being worked by Mr. Hartman at Point View. The Harbison-Walker Refractories Company has extensive quarries on Tussey Mountain where it is cut by Juniata River.

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The quantity of ganister that can be obtained in the way described above is very great. The mantle of rock waste along or near the crests of the ridges extends for miles and is so thick that very little vegetation can grow upon it, so that its white glistening surface is visible for great distances. The supply obtainable from the formation in place is, of course, practically inexhaustible, but on account of the great toughness of the rock quarrying is very expensive.

QUALITIES OF GANISTER.

The question naturally arises, What are the qualities of ganister that make it suitable for silica brick while ordinary sandstone of the same composition is not suitable? There seems to be a difference of opinion on these points. J. D. Hartman, jr., states that sandstone is worthless for silica brick, as the brick "volatilize" at a high temperature, allowing the walls of the furnace to fall in. His idea plainly is that brick made from ordinary sandstone are not sufficiently refractory. On the other hand, William Walker, of the Harbison-Walker Refractories Company, says that brick made from sandstone, even though of greater purity than the ganister rock, are not sufficiently strong mechanically to endure handling without breaking. His idea appears to be that the brick lack strength rather than refractoriness. The writer knows of no reason why silica derived from a more or less loosely cemented sandstone should fuse at a lower temperature than that from a compactly cemented quartzite like the ganister rock. It appears probable, therefore, that the adaptability of ganister for brick is due to the superior strength of the brick made from it, and this difference in strength is easily explainable by the difference in physical structure between the ganister and sandstone. In ganister the constituent grains, being firmly cemented together, do not separate in crushing but the whole mass breaks up into angular fragments and slivers which can be pressed together into a cohering mass in molding and so make a brick that will not break easily in handling; whereas loosely cemented sandstone pulverizes more or less completely into its constituent rounded grains, which do not interlock in molding and so have but little coherence and make a weak brick.

PROCESSES OF MANUFACTURE.

The ganister rock is crushed to the size of ordinary railroad ballast or finer, a Blake jaw crusher being found most satisfactory. It is then passed in charges of 1,200 pounds to a wet pan and ground to sizes ranging from dust to particles one-fourth inch in longer diameter. In this stage 1.5 per cent of milk of lime is added to bond the material suffi-

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ciently to permit handling in the operations between the grinding pan and the kiln. After molding, the brick are passed through drying tunnels in which they remain from sixteen to forty-eight hours, depending on the weather; then they are put into the kiln and stacked on edge so as to expose the greatest surface to the heat. The kilns are of square down-draft type. The time of burning is ten days—three days to bring the brick up to the temperature of burning, four days for burning, and three days for gradual cooling. The highest temperature reached is about 2,500° F.

CHARACTER OF BRICK.

The composition of silica brick as made from Blair County ganister by two different companies is shown below.

Composition of silica brick made from ganister in Blair County, Pa.

	1.	2.
Silica	96.06	95.06
Oxide of iron	.535	1.21
Oxide of manganese	.04	.....
Alumina	.935	1.79
Lime	1.45	1.79
Magnesia	.526	Trace.
Potash	.146	.....
Soda	.045	.....

The lime shown in these analyses is due to that added for bonding the crushed material. The other substances, except silica, are regarded as impurities, but in the quantities shown they do not impair the quality of the brick, for such brick will have a melting point of approximately 3,500° F., which is about 200° hotter than open-hearth steel furnaces. It is even probable that the slight amount of impurities is advantageous, as if the brick were made from an absolutely pure silica rock it would be almost impossible to burn them hard enough, on a commercial scale, to be sufficiently coherent. With the exception of alumina, these substances have a fluxing effect. More than 1.25 per cent of iron oxide in the ganister practically ruins the brick, however.

The crushing strength of these brick ranges from 2,500 to 3,500 pounds to the square inch, which is far beyond any requirements in actual use.

USES OF GANISTER BRICK.

The silica brick made from this ganister are used for the sides and crowns of open-hearth steel furnaces, continuous glass furnaces, and any other furnaces which require a highly refractory brick and in which the temperature does not undergo sudden changes, and also

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in which the brick do not come into contact with material that would flux with the brick. The bottoms of steel furnaces, for example, are made of other material, such as magnesia brick. Blast-furnace linings are not made of silica brick because they are not able to resist the action of the molten metal pressing against the sides of the furnaces.

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SURVEY PUBLICATIONS ON CEMENT AND CEMENT AND CONCRETE MATERIALS.

The following list includes the principal publications on cement materials by the United States Geological Survey, or by members of its staff. The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Besides the publications cited, the Survey has in preparation numerous bulletins dealing with the results of tests on concrete beams and the constituent materials of concrete, etc.

ADAMS, G. I., and others. Economic geology of the Iola quadrangle, Kansas. Bulletin No. 238. 80 pp. 1904.

BALL, S. H. Portland cement materials in eastern Wyoming. In Bulletin No. 315, pp. 232–244. 1907.

BASSLER, R. S. Cement materials of the Valley of Virginia. In Bulletin No. 260, pp. 531–544. 1905. 40c.

BURCHARD, E. F. Portland cement materials near Dubuque, Iowa. In Bulletin No. 315, pp. 225–231. 1907.

——— Concrete materials produced in the Chicago district. In Bulletin No. 340, pp. 383–410. 1908.

BUTTS, C. Sand-lime brickmaking near Birmingham, Ala. In Bulletin No. 315, pp. 256–258. 1907.

CATLETT, C. Cement resources of the Valley of Virginia. In Bulletin No. 225, pp. 457–461. 1904. 35c.

CLAPP, F. G. Limestones of southwestern Pennsylvania. Bulletin No. 249. 52 pp. 1905.

CRIDER, A. F. Cement resources of northeast Mississippi. In Bulletin No. 260, pp. 510–521. 1905. 40c.

——— (See also Eckel, E. C., and Crider, A. F.)

CUMMINGS, U. American rock cement. A series of annual articles on natural cements, appearing in the volumes of the Mineral Resources U. S. previous to that for 1901.

DARTON, N. H. Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming. Professional Paper 65. 104 pp. 1909.

——— Structural materials near Portland, Oreg., and Seattle and Tacoma, Wash. Bulletin No. 387. — pp. 1909.

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DARTON, N. H. and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming. Bulletin No. 364. 81 pp. 1908.

DURYEE, E. Cement investigations in Arizona. In Bulletin No. 213, pp. 372–380. 1903. 25c.

ECKEL, E. C. Slag cement in Alabama. In Mineral Resources U. S. for 1900, pp. 747–748. 1901. 70c.

——— The manufacture of slag cement. In Mineral Industry, vol. 10, pp. 84–95. 1902.

——— The classification of the crystalline cements. In Am. Geologist, vol. 29, pp. 146–154. 1902.

——— Portland cement manufacturing. In Municipal Engineering, vol. 24, pp. 335–336; vol. 25, pp. 1–3, 75–76, 147–150, 227–230, 405–406. 1903.

——— The materials and manufacture of Portland cement. In Senate Doc. No. 19, 58th Cong., 1st sess., pp. 2–11. 1903.

——— Cement-rock deposits of the Lehigh district. In Bulletin No. 225, pp. 448–450. 1904. 35c.

——— Cement materials and cement industries of the United States. Bulletin No. 243. 395 pp. 1905. 65c.

——— The American cement industry. In Bulletin No. 260, pp. 496–505. 1905. 40c.

——— Portland cement resources of New York. In Bulletin No. 260, pp. 522–530. 1905. 40c.

——— Cement resources of the Cumberland Gap district, Tennessee-Virginia. In Bulletin 285, pp. 374–376. 1906. 60c.

——— Advances in cement technology, 1906. In Mineral Resources U. S. for 1906, pp. 897–905. 1907.

——— Lime and sand-lime brick. In Mineral Resources U. S. for 1906, pp. 985–991. 1907. 50c.

——— Cement industry in the United States in 1907. In Mineral Resources U. S. for 1907, pt. 2, pp. 477–493. 1908.

——— Lime and sand-lime brick. In Mineral Resources U. S. for 1907, pt. 2, pp. 545–551. 1908.

ECKEL, E. C., and CRIDER, A. F. Geology and cement resources of the Tombigbee River district, Mississippi-Alabama. Senate Doc. No. 165, 58th Cong., 3d sess. 21 pp. 1905.

ENGSTROM, R. V. (See Humphrey, R. L., and Engstrom, R. V.)

HUMPHREY, R. L. The effects of the San Francisco earthquake and fire on various structures and structural materials. In Bulletin No. 324, pp. 14–61. 1907. 50c.

——— Organization, equipment, and operation of the structural-materials testing laboratories at St. Louis, Mo. Bulletin No. 329. 85 pp. 1908.

——— (in charge). Portland cement mortars and their constituent materials: Results of tests, 1905 to 1907. Bulletin No. 331. 130 pp. 1908.

——— The strength of concrete beams; results of tests made at the structural-materials testing laboratories. Bulletin No. 344. 59 pp. 1908.

——— The fire-resistive properties of various building materials. Bulletin No. 370. 99 pp. 1909.

HUMPHREY, R. L., and ENGSTROM, R. V. Investigations of concrete and reinforced concrete at ten technological institutions. (In preparation.)

KIMBALL, L. L. Cement. A series of annual articles on the cement industry and the production of cement in the United States. In Mineral Resources U. S. for 1901, 1902, 1903, 1904, and 1905.

LANDES, H. Cement resources of Washington. In Bulletin No. 285, pp. 377–383. 1906. 60c.

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NEWBERRY, S. B. Portland cement. A series of annual articles on Portland cements, appearing in the various volumes of the Mineral Resources U. S. previous to that for 1901.

RICHARDSON, G. B. Portland cement materials near El Paso, Tex. In Bulletin No. 340, pp. 411–414. 1908.

RUSSELL, I. C. The Portland cement industry in Michigan. In Twenty-second Ann. Rept., pt. 3, pp. 620–686. 1902.

SEWELL, J. S. The effects of the San Francisco earthquake on buildings, engineering structures, and structural materials. In Bulletin No. 324, pp. 62–130. 1907. 50c.

SIEBENTHAL, C. E. (See Darton, N. H., and Siebenthal, C. E.)

SMITH, E. A. The Portland cement materials of central and southern Alabama. In Senate Doc. No. 19, 58th Cong., 1st sess., pp. 12–23. 1903.

——— Cement resources of Alabama. In Bulletin No. 225, pp. 424–447. 1904. 35c.

TAFF, J. A. Chalk of southwestern Arkansas, with notes on its adaptability to the manufacture of hydraulic cements. In Twenty-second Ann. Rept., pt. 3, pp. 687–742. 1902.

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CLAYS.

NOTES ON THE CLAYS OF FLORIDA.

By GEORGE C. MATSON.

INTRODUCTION.

Timber is so abundant in the South Atlantic and Gulf States that heretofore wood has been the principal building material in common use. The increase in wealth and the growth of towns and cities, however, have caused an increasing demand for more substantial structural materials. This demand has been met by the use of products manufactured from clay. In some States clay products have been made in a variety of forms; but in Florida little attention has been given to anything except common building brick, though in one locality, near Pensacola, some front and fire brick are produced and a plant was formerly operated for the manufacture of red earthenware. The recent development of subirrigation for truck gardening has created a market for tile, which has been in part supplied by pipes made of cement and in part by ordinary clay tile. Tile of this kind is commonly known as drain tile, but in Florida it is seldom used for drainage purposes.

In addition to the supply necessary to meet the home demand, considerable clay is mined in Florida and shipped to some of the Northern States, being sold under the name of ball clay and used for the manufacture of pottery. Upon his return from a recent trip to Florida Dr. D. T. Day reported that a plant had been established at Jacksonville for the manufacture of pottery.

In Florida the brickmaking industry is most active near the large centers of population where there is a good demand for the product, but small plants are also situated at various localities in the northern part of the State where clay is abundant. The total number of factories in operation is about 27, distributed in thirteen different counties. The factories are most numerous in the counties near the northern line of the State, because the clay deposits are there most

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abundant. Clay occurs also in the central part of the peninsula, where deposits suitable for brickmaking are known to exist in Alachua, Putnam, and Lake counties. The most southerly points where brick are manufactured are at Tampa, in Hillsboro County, and near Auburndale, in Polk County. It is probable that brick clays could be obtained in most of the counties which lie in the upland portion of the peninsula. Valuable clays for brick manufacture occur also at various points in the St. Johns Valley from Palatka northward. Ball clays are being mined in Putnam and Lake counties, and it seems probable that the area of workable deposits may extend into some of the adjoining counties.

The rocks of Florida are all either of Tertiary or Quaternary age; and the geologic section of the State comprises representatives of each period from the close of the Eocene to the present time. With the exception of the lower Oligocene, each of the major subdivisions contains more or less clay. A generalized geologic section of Florida is given below.

Generalized geologic section of Florida.

	Approximate thickness (feet).	Character.
Quaternary:		
Recent	10	Sand, peat, muck, marl, and coquina; clay in small areas on the flood plains of some of the streams.
Pleistocene	100	Sand, marl, and coquina; clay not abundant, but good deposits of moderate extent occur locally—for example, near Middleburg, Clay County.
Tertiary:		
Pliocene—		
Clays and sands	20–50	Cross-bedded red and yellow sands with some pebbles; clay is widely distributed in this formation, but is usually sandy; Lafayette formation, doubtfully Pliocene.
Fossiliferous shell marls	20	No clays.
Phosphatic gravels	30	No clays of importance.
Clays	10	Sandy blue clays occurring in depressions in the Oligocene limestone; Alachua clay.
Miocene—		
Clay	25	Plastic bluish or greenish-gray clays; "aluminous" clay.
Fossiliferous shell marls	50	No clays.
Limestones, sands, silex, and clays.	500	Known chiefly from well records; no clay beds of economic importance.
Oligocene—		
Upper	250	Limestones, marls, sands, clays, and fuller's earth. Clays and fuller's earth occur in the upper part of the section, and clays are found locally near the base.
Lower	1,000	Soft white limestone. No clay.

OLIGOCENE CLAYS.

The lower Oligocene is practically all limestone and consequently not important in this discussion. The upper Oligocene includes beds of clay of considerable thickness and fuller's earth beds in both the northern and southern parts of the State. The brick clays are light green to greenish gray in color and very plastic, and although

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they are well exposed they are not extensively utilized for the manufacture of clay products. The section in the pit at the Tampa Brick Company's plant shows 2 to 4 feet of white Pleistocene sand resting unconformably upon 10 feet of light-green upper Oligocene siliceous clay containing some nodular beds of carbonate of lime near the base. Scattered throughout the clay are many bowlders and cobbles of chert consisting of silicified corals.

The following analysis represents a sample of clay from the upper Oligocene near Tampa. Although the sample was not taken from the clay pit at the brickyard, it is probably fairly representative of the character of the clay at that locality.

Analysis of clay from Tampa.

[Collected by W. H. Dall; analyzed by L. G. Eakins.[a]]

SiO_2	70.78
$Al_2O_3+Fe_2O_3$	11.33
MgO	-----
CaO	2.18
H_2O	14.55
	100.98

This analysis is incomplete, but shows the general character of the clay. Clay from this horizon is now being used for the manufacture of good building brick, and it might possibly be made into paving brick, an article greatly needed in the peninsula of Florida. However, before attempts are made to use it for that purpose it should be subjected to practical tests to determine its value.

Clay similar to that at the Tampa brickyard outcrops on the shore near Clearwater, and well records indicate that a short distance from the coast it attains a thickness of 8 to 12 feet and is covered by 10 feet of coarse Pleistocene sand. About 1 mile north of Espiritu Santo Springs the following section was noted:

Section 1 mile north of Espiritu Santo Springs.

	Feet.
White sandy loam, Pleistocene	2–4
Slightly indurated dark-brown sand, Pleistocene	1½
Light-green siliceous clay, upper Oligocene	0–5

The clay at this place closely resembles that at the Tampa brickyard. The deposit is favorably located on the shore of the bay, and it might be possible to work the clay and ship the product to Tampa by water.

[a] Bull. U. S. Geol. Survey No. 228, 1904, p. 355.

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A sample of Oligocene clay was collected from the Sandlin place, about 2 miles southeast of Marion, Hamilton County, and was analyzed with the following result :

Analysis of clay from Sandlin place, 2 miles southeast of Marion, Hamilton County.

[Collected by G. H. Eldridge; analyzed by H. N. Stokes.[a]]

SiO_2	78.23
Al_2O_3	1.85
Fe_2O_3	1.85
FeO	-----
MgO	2.11
CaO	1.60
H_2O at 100°	[b] 8.48
H_2O above 100°	
P_2O_5	Trace.
CO_2	-----
	99.57

The high silica content indicates that this clay is likely to be somewhat refractory, but it should prove satisfactory for the manufacture of ordinary brick. It is very plastic and of light-drab, blue, or greenish color. Similar clay is widely distributed in Florida. It probably lies at about the horizon represented by the clays near Lee and the clays and fuller's earth beds near Quincy, River Junction, and Jamieson. The thickness of individual beds does not as a rule exceed 10 feet; but the clay should prove of value for manufacturing where it is not deeply buried and is situated within easy reach of a suitable market.

Clay of a quality similar to that described above was observed on Suwannee River at White Springs, and it is also reported farther down the same stream. Well records show that light-green clay attains a thickness of about 70 feet near Newmansville,[c] and detailed investigations would probably show that this clay outcrops in some of the counties to the north.

Some clays from the upper Oligocene of Florida were collected by T. W. Vaughan and sent to Heinrich Ries for examination. The results of the tests made, together with Vaughan's notes, are incorporated in a previous report.[d] A sample of white calcareous clay was obtained on a hillside in sec. 1, T. 1 S., R. 4 W., on property owned by W. B. Stoutamire, about 18 miles southwest of Tallahassee.[e]

[a] Bull. U. S. Geol. Survey No. 228, 1904, p. 356.
[b] Includes a little CO_2.
[c] Dall, W. H., Neocene of North America; Bull. U. S. Geol. Survey No. 84, 1892, p. 109.
[d] Ries, Heinrich, Clays of the United States east of the Mississippi River: Prof. Paper U. S. Geol. Survey No. 11, 1903, pp. 83–85.
[e] Idem, p. 83.

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The chemical composition of the clay is indicated by the following analysis:

Analysis of clay from Leon County, Fla.

[Analyst, H. Ries.]

SiO_2	35.95
Al_2O_3	13.23
Fe_2O_3	1.27
CaO	15.00
MgO	5.40
H_2O	10.55
Moisture	
CO_2	18.50
	99.90

Another sample, which is described as brick clay, was obtained on the property of J. D. Stoutamire, in sec. 15, T. 1 S., R. 4 W.[a] This clay burns to a light-buff color and it is thought that a sufficient admixture of sand would make it available for the manufacture of front brick.

Calcareous clay was also obtained on W. W. Williams's farm in sec. 21, T. 1 S., R. 4 W.[a] The outcrop is in the bed of a small creek about one-half mile southeast of Jackson Bluff on Ochlocknee River. The thickness of the exposure of clay is only 2½ feet, and it is overlain by about 6 feet of sandy alluvium. The tests indicated that this clay had too high a shrinkage to be used alone, but it might be suitable for mixture with other clays to serve as a binding material. Its value for this purpose was suggested by the fact that it has a high tensile strength, ranging from 300 to 388 pounds to the square inch.[b] The chemical composition is given below:

Analysis of calcareous clay from land of W. W. Williams, near Jackson Bluff, Ochlocknee River, Florida.

[Analyst, H. Ries.]

Silica	30.83
Alumina	15.40
Ferric oxide	1.40
Lime	13.78
Magnesia	7.50
Alkalies	Undetermined.
Carbon dioxide	20.14
Water	7.16
	96.21

[a] Ries, Heinrich, Clays of the United States east of the Mississippi River: Prof. Paper U. S. Geol. Survey No. 11, 1903, p. 84.

[b] Idem, p. 85.

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MIOCENE CLAYS.

The Miocene beds which are exposed in Florida consist largely of marl and limestone, but a bed of calcareous clay of considerable thickness occurs above the marls in some localities. This deposit outcrops at Alum Bluff, where it consists of light-gray to greenish-gray clay. The presence of a white efflorescence upon the surface of the clay led to the use of the name Alum Bluff for the exposure at this locality. The use of the term "aluminous"[a] clay appears to be unfortunate, as it is likely to be misleading. So far as now known, no clays of Miocene age are being extensively utilized in Florida, though it appears probable that the deposit described above might prove valuable.

PLIOCENE CLAYS.

Clays of Pliocene age are widely distributed in northern Florida and extend some distance southward along the elevated axis of the peninsula. The clays near the northern boundary belong to the Lafayette formation and those in the central part of the peninsula form the Alachua clay. The clays of the Lafayette formation are probably more extensively used than those from any other geologic formation in the State. The occurrence of the clay beds is very irregular, and the thickness of some of them varies within short distances. The clays are plastic and have a great variety of colors, ranging from nearly white and mottled gray to various shades of blue, red, or yellow. They usually carry a high percentage of rather coarse sand that prevents excessive shrinking on drying, but often gives the burned product a rough appearance and renders it porous. However, when properly mixed and burned the clays of the Lafayette formation make a very good brick for ordinary building purposes.

The Alachua clay is widely distributed, but occurs as discontinuous patches. It is usually plastic, and the color is commonly light gray to bluish gray, except on weathered surfaces, where light yellow or red colors prevail. Like the clays of the Lafayette formation, the Alachua clay is liable to be sandy, and hence is best adapted to the production of common building brick.

The clay of the McMillan Brick Company's pit, one-half mile north of Molino, is referred to the Lafayette, though the thickness of the workable deposit at that locality is unusually great for this formation. The material is very plastic and is utilized for the manufacture of building brick. A section which was roughly measured in the pit southwest of the factory gave 5 to 8 feet of red and yellow stratified sands with laminæ of clay, underlain by 25 feet of very plastic dense

[a] Dall, W. H., and Stanley-Brown, Joseph, Cenozoic geology along the Apalachicola River; Bull. Geol. Soc. America, vol. 5, 1894, p. 157.

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blue clay. The clay in this section contains much less sand than is commonly found in the Pliocene clays of Florida, and this fact, together with its thickness, makes the deposit somewhat more valuable than the average.

PLEISTOCENE CLAYS.

The Pleistocene beds of Florida consist largely of sand, but a few local deposits of clay have been discovered. Though most of these clays are sandy, there are a few localities where the beds are exceptionally free from grit. This is the case on Black Creek, in Clay County, where the Union Brick Company is working an extensive deposit of very pure plastic clay, which makes a building brick of good quality. The section given below was roughly measured in the pit of this company. The locality is about one-fourth mile north of Black Creek and 2 miles below Middleburg.

Section in pit of Union Brick Company near Black Creek.

	Ft.	In.
Light-gray sandy loam, Pleistocene		6–8
Very plastic light-blue clay, showing thin lamination, Pleistocene	6–12	
Erosion unconformity.		
Fine white sand with patches of yellow clay at the top	3+	

The light-blue clay shows columnar jointing and is weathered to a bright red along joints near the surface. A few small concretions of lime occur scattered through the deposit.

The analysis given below represents a sample of clay obtained at Melborne Creek. The exact location of the exposure from which the sample was obtained is not known, but the deposit is probably of Pleistocene age.

Analysis of hammock clay from Melborne Creek.

[Collected by N. S. Shaler; analyzed by L. G. Eakins.[a]]

SiO_2	38.04
$Al_2O_3+Fe_2O_3$	27.19
MgO	.46
CaO	10.73
H_2O	10.73
H_2O, including some CO_2	23.61
	100.03

To judge from the analysis, this clay should prove valuable for brick manufacture, provided a large enough quantity could be obtained to warrant the construction of a factory.

[a] Bull. U. S. Geol. Survey No. 228, 1904, p. 355.

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RECENT CLAYS.

Some Recent clays are being mined for the manufacture of brick about 1 mile west of Chipley. The deposit at this locality consists of a light-blue alluvial clay which forms the flood plain of the stream. The surface lies very near water level, and hence no attempt has been made to mine the clays to a depth of more than 3 to 4 feet. The full thickness of the beds has not been determined, but they may extend to more than twice the depth of the present pit; if so, the deposit could be worked on a large scale. The absence of overburden makes it possible to mine the clay cheaply, and the presence of water in the pit is the only serious disadvantage. However, the excavation could probably be carried on without serious inconvenience by means of a steam shovel. This clay is sufficiently plastic to be molded by the stiff-mud process, and the burned product varies in color from pale yellow to red, depending on the thoroughness of the oxidation of the iron present. The lighter colors are characteristic of underburning, and dark colors are a sign of imperfect oxidation due to the exclusion of air or to the application of heat too rapidly.

PLIOCENE (?) BALL CLAYS.

In Putnam and Lake counties there are a number of pits that produce a plastic white clay commonly known as "kaolin." This clay bears a strong resemblance to kaolin, but differs from it in origin. According to Ries,[a] the term kaolin is usually restricted to the white-burning clays, of residual origin, which consist of silica, alumina, combined water, and a very small percentage of fluxing compounds. The so-called "kaolins" of Florida are of sedimentary origin, and consequently do not meet the requirements of the above definition. They are known to some extent as ball clays. The deposit in Putnam County consists of a conglomerate or coarse sand with probably 30 to 40 per cent of argillaceous matter. The clay, when separated from the sand and gravel, forms a white fine-grained mass, resembling pure kaolin. It burns white, is very plastic, and is sufficiently free from fluxing compounds to be fairly refractory. The tensile strength of the air-dried clay is sufficient to enable it to retain its form with considerable tenacity. This fact, together with the color and refractoriness, makes it possible to use the clay for the manufacture of white earthenware. The manufacturing is mostly done outside the State.

The area covered by the ball-clay deposits is not very clearly defined. Mining is now being carried on at Edgar, Johnson, and McMeekin, in Putnam County, and at Yalaha, Okahumpka, and Richmond, in Lake County. In Lake County the deposit is said to lie along both sides of Palatkaha Creek for a distance of 25 or 30

[a] Ries, Heinrich, Clays; their occurrence, properties, and uses, 1906, p. 165.

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miles. The following description is taken from the unpublished notes of George H. Eldridge:

Kaolin occurs on the property of Dr. J. F. Richmond, not far from Okahumpka. The pits and outcrops lie along the Palatkaha, extending from the doctor's house a distance of 2½ miles upstream and perhaps a short distance in the opposite direction. The beds have been prospected between a quarter and a half mile back from the stream on the east side and about the same distance west of the stream, but in the latter case not so thoroughly as in the former. Pits were examined in the NW. ¼ NE. ¼ sec. 23, T. 20, R. 24; the NE. ¼ NW. ¼ sec. 26, T. 20, R. 24; and the NE. ¼ SE. ¼ and the SE. ¼ NE. ¼ sec. 14, T. 20, R. 24. The material has been used for making pottery and ornamental tile. It was shipped to New York to a factory located on the Hudson River. The deposit occurs in a bluff 2 to 10 feet high along the river. It is essentially a mixture of quartz and clay, both usually white. The relative proportions vary from a nearly pure sandstone or grit to a rather pure clay. The material is said to contain 50 per cent of clay. About one-half mile from the house is a mottled pink or yellowish-white sand with occasional more or less clayey patches. The exact thickness of the clay bed is not known, but it is supposed to be about 20 feet.

The Putnam County ball clays probably occupy a considerable area west of Palatka, and they may extend beyond the boundary of the county. This deposit is reported to have a maximum thickness of about 30 feet. The following section is given by Ries:[a]

Section in clay pit at Edgar, Fla.

	Feet.
Top soil	8
Impure upper clay	8–10
White clay	25
Green clay.	

The thickness of the green clay was not determined. According to Eldridge, this clay was elsewhere observed resting upon limestone, and there appears to be little doubt that it belongs to the Upper Oligocene. The age of the ball-clay deposit has not been definitely determined, but it may be Pliocene.

The following mention of ball clay is contained in a report by Ries:[b]

According to Mr. W. T. Vaughan, of the United States Geological Survey, who has been doing field work on the Tertiary formations of northern Florida and southwestern Georgia, another deposit of ball clay occurs on the land of Mr. Augustus Munroe, sec. 32, T. 10 S., R. 23 E. Mr. Vaughan states that—

"The material is very sandy, but its thickness could not be ascertained from observation. Several auger holes had been sunk, and these indicate a thickness of about 10 feet. The bed is said to be thicker near the summit of the hill. The overburden varies from 4 to 10 feet, and the deposit can be economically worked over an area of several acres. The transportation facilities are good, as the Plant System railway is only a half mile distant."

[a] Ries, Heinrich, Clays of the United States east of the Mississippi River: Prof. Paper U. S. Geol. Survey No. 11, 1903, p. 82.

[b] Idem, p. 83.

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A weathered deposit of argillaceous sand resembling unwashed ball clay is mined for road metal near Interlachen, and similar material is being obtained west of Palatka. Other deposits of like character are reported at Bartow Junction, Winter Haven, and Arcadia. None of the material from these localities has been tested to determine its value for manufacturing, but the deposit at Arcadia is said to be valuable for road building, and it is probable that the clays from the other localities mentioned might be used for a similar purpose. At Bartow Junction the beds weather to a bright-yellow or mottled color, owing to the presence of iron oxide, and hence the material is probably unfit for use where a white burned product is desired. These beds are covered by the gray Pleistocene sand common to the region. The deposits are ordinarily 10 to 12 feet or more in thickness, and as they are near the surface they can be worked advantageously. Roads treated with the unwashed mixture of gravel and clay are far superior to the sandy thoroughfares common in the region.

Several analyses of Florida ball clays and two analyses of the more ferruginous beds at Bartow Junction are given below.

Analyses of Florida ball clay.

	1.	2.	3.	4.	5.
SiO_2	46.11	45.39	84.41	79.99	79.48
Al_2O_3	39.5	39.19	11.02	10.82	12.14
Fe_2O_3	.35	.45	Trace.	3.25	2.64
FeO				.25	.09
MgO	.13	.29	Trace.	.07	.07
CaO		.51	.20	.23	.31
H_2O at 100°	[a] 13.78	[a] 14.01	[b] 4.25	[b] .90	.86
H_2O above 100°				4.09	4.73
P_2O_5			Trace.		
CO_2				None.	None.
SO_3	.07				
Alkalies		.83			
	99.94	100.67	99.88	99.87	100.32

[a] Stated as "water" in the original publication.
[b] Includes a little CO_2.

Localities: 1, Washed clay from Palatkaha River; 2, washed clay from Edgar; 3, raw clay from Richmond's, 6 miles south of Leesburg; 4 and 5, clay from Bartow Junction.

Sources of analyses: 1 and 2, Ries, Heinrich, Clays of the United States east of the Mississippi River: Prof. Paper, U. S. Geol. Survey No. 11, 1903, p. 83; 3, 4, and 5, collected by Geo. H. Eldridge, 3 analyzed by H. N. Stokes, 4 and 5 by George Steiger; Bull., U. S. Geol. Survey No. 228, 1904, p. 356.

The first two analyses represent the ball clay after it has been prepared for market by washing; the third shows the character of the raw material. It is interesting to note that the difference between the original clay and the washed material is practically all due to a lowering in the percentage of silica. This is brought about by the removal of quartz sand and pebbles in the process of washing.

The samples from Bartow Junction (4 and 5) show a remarkable similarity to the raw ball clay represented by analysis 3. In fact,

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the only important difference is an increase in the amount of iron present and a corresponding decrease in the quantity of silica. The ball clay is valued because it is refractory and burns white. The material at Bartow Junction lacks these two characteristics, and hence it could not be used for the production of white pottery. It might, however, be useful for the manufacture of colored ware, and its similarity to the ball clay suggests that it might be worth while to prospect elsewhere for deposits similar to those in Putnam and Lake counties.

METHODS OF MINING AND MANUFACTURING.

The ball clay is mined by dredging. The pit is kept partly full of water, supplied by a flowing well, and a float is used for dredging purposes. On this float are an engine, a scraper, and a pump. The engine is used to operate the scraper, which loosens the material, and the pump, which elevates the loosened sand and clay to the washing troughs. In these troughs the clay is separated from the sand and gravel, and it is then carried to a shed where it is squeezed between circular wooden disks to remove the excess of water. The material obtained in this manner is said to be of excellent quality and is shipped to the factory to be manufactured into pottery.

The brick clays of Florida are all mined by means of open pits, few of which exceed 25 to 30 feet in depth. It is usually necessary to remove the covering of Pleistocene sand that rests on the clays at most localities, but as this deposit is thin the cost of stripping is small. In most of the brickyards the clay is excavated by means of pick and shovel and loaded on small cars which are drawn up an inclined track to the shed where the molding is done. The clay is dumped from the car automatically into the pug mill, where it is thoroughly mixed and forced into the molding machine. In most plants the bricks are made by what is called the stiff-mud process, but in some brickyards the soft-mud process is used. From the molds the bricks are conveyed to the drying sheds, either on small cars or by means of a broad belt which extends from the molding machine across the shed.

After being air dried, the bricks are taken from the sheds and placed in the kiln. In many brickyards the burning is done in temporary kilns that are constructed each time that a number of bricks are ready for burning. In these kilns the heat is supplied by wood fires and is distributed by an upward draft through the openings left between the bricks. In a few yards permanent kilns are used, the heat being supplied in the same manner as in the temporary kilns, except that the bricks are so arranged that there is a downward as well as an upward draft. This method of burning is more economical than the other and gives better results.

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Practically all the clays which are now being utilized for brick and tile manufacture burn to a bright-red or yellow color at comparatively low temperatures. However, the products of the kilns frequently show every gradation in color from light buff to nearly black. These variations are usually due to imperfect oxidation of the iron compounds present, the lighter colors resulting from burning at too low a temperature and the darker from lack of sufficient air to furnish oxygen. With clays containing both lime and iron, however, a buff color may result, even when the clays are properly burned.

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SURVEY PUBLICATIONS ON CLAYS, FULLER'S EARTH, ETC.

In addition to the papers named below, some of the publications listed under the heading "Cement" contain references to clays. Certain of the geologic folios also contain references to clays, fuller's earth, etc.

These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Those marked "Exhausted" are not available for distribution, but may be seen at the larger libraries of the country.

ASHLEY, G. H. Notes on clays and shales in central Pennsylvania. In Bulletin No. 285, pp. 442–444. 1906.

BASTIN, E. S. Clays of the Penobscot Bay region, Maine. In Bulletin No. 285, pp. 428–431. 1906.

BRANNER, J. C. Bibliography of clays and the ceramic arts. Bulletin No. 143. 114 pp. 1896. Exhausted.

——— The clays of Arkansas. Bulletin No. 351. 1908.

BUTTS, C. Clays of the Birmingham district, Alabama. In Bulletin No. 315, pp. 291–295. 1907.

CRIDER, A. F. Clays of western Kentucky and Tennessee. In Bulletin No. 285, pp. 417–427. 1906.

DARTON, N. H. Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming. Professional Paper No. 65. (In press.)

DARTON, N. H., and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming; a preliminary report. Bulletin No. 364. 1909.

ECKEL, E. C. Stoneware and brick clays of western Tennessee and northwestern Mississippi. In Bulletin No. 213, pp. 382–391. 1903. 25c.

——— Clays of Garland County, Ark. In Bulletin No. 285, pp. 407–411. 1906.

FENNEMAN, N. M. Clay resources of the St. Louis district, Missouri. In Bulletin No. 315, pp. 315–321. 1907.

FISHER, C. A. The bentonite deposits of Wyoming. In Bulletin No. 260, pp. 559–563. 1905. 40c.

——— Clays in the Kootenai formation near Belt, Mont. In Bulletin No. 340, pp. 417–423. 1908.

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FULLER, M. L. Clays of Cape Cod, Massachusetts. In Bulletin No. 285, pp. 432–441. 1906.

GARDNER, J. H. (See Shaler, M. K., and Gardner, J. H.)

HAWORTH, E. (See Schrader, F. C., and Haworth, E.)

HILL, R. T. Clay materials of the United States. In Mineral Resources U. S. for 1891, pp. 474–528. 1892. 50c.

HILL, R. T. Clay materials of the United States. In Mineral Resources U. S. for 1892, pp. 712–738. 1893. 50c.

LANDES, H. The clay deposits of Washington. In Bulletin No. 260, pp. 550–558. 1905. 40c.

LINES, E. F. Clays and shales of the Clarion quadrangle, Clarion County, Pa. In Bulletin No. 315, pp. 335–343. 1907.

MARBUT, C. F. (See Shaler, N. S., Woodworth, J. B., and Marbut, C. F.)

MARTIN, LAWRENCE. (See Phalen, W. C., and Martin, Lawrence.)

MIDDLETON, J. Clay-working industries. In Mineral Resources U. S. for 1907, pt. 2, pp. 495–556. 1908.[a]

PHALEN, W. C. Clay resources of northeastern Kentucky. In Bulletin No. 285, pp. 412–416. 1906.

——— Economic geology of the Kenova quadrangle, Kentucky, Ohio, and West Virginia. In Bulletin No. 349, pp. 112–122. 1908.

PHALEN, W. C., and MARTIN, LAWRENCE. Clays and shales of southwestern Cambria County, Pa. In Bulletin No. 315, pp. 344–354. 1907.

PORTER, J. T. Properties and tests of fuller's earth. In Bulletin No. 315, pp. 268–290. 1907.

RIES, H. Technology of the clay industry. In Sixteenth Ann. Rept., pt. 4, pp. 523–575. 1895. $1.20.

——— The pottery industry of the United States. In Seventeenth Ann. Rept., pt. 3, pp. 842–880. 1896.

——— The clays of the United States east of the Mississippi River. Professional Paper No. 11. 298 pp. 1903. 40c.

SCHRADER, F. C., and HAWORTH, E. Clay industries of the Independence quadrangle, Kansas. In Bulletin No. 260, pp. 546–549. 1905. 40c.

SHALER, M. K., and GARDNER, J. H. Clay deposits of the western part of the Durango-Gallup coal field of Colorado and New Mexico. In Bulletin No. 315, pp. 296–302. 1907.

SHALER, N. S., WOODWORTH, J. B., and MARBUT, C. F. The glacial brick clays of Rhode Island and southeastern Massachusetts. In Seventeenth Ann. Rept., pt. 1, pp. 957–1004. 1896.

SIEBENTHAL, C. E. Bentonite of the Laramie Basin, Wyoming. In Bulletin No. 285, pp. 445–447. 1906.

SIEBENTHAL, C. E. (See Darton, N. H., and Siebenthal, C. E.)

STOSE, G. W. White clays of South Mountain, Pennsylvania. In Bulletin No. 315, pp. 322–334. 1907.

VAN HORN, F. B. Fuller's earth. In Mineral Resources U. S. for 1907, pp. 731–734, pt. 2. 1908.

VAUGHAN, T. W. Fuller's earth of southwestern Georgia and Florida. In Mineral Resources U. S. for 1901, pp. 922–934. 1902.

——— Fuller's earth deposits of Florida and Georgia. In Bulletin No. 213, pp. 392–399. 1903. 25c.

VEATCH, O. Kaolins and fire clays of central Georgia. In Bulletin No. 315, pp. 303–314. 1907.

[a] Previous volumes of the Mineral Resources of United States contain chapters devoted to clay and the clay-working industries of the United States.

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WILBER, F. A. Clays of the United States. In Mineral Resources U. S. for 1882, pp. 465–475. 1883. 50c.

——— Clays of the United States. In Mineral Resources U. S. for 1883–84, pp. 676–711. 1885. 60c.

WOODWORTH, J. B. (See Shaler, N. S., Woodworth, J. B., and Marbut, C. F.)

WOOLSEY, L. H. Clays of the Ohio Valley in Pennsylvania. In Bulletin No. 225, pp. 463–480. 1904. 35c.

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LIME AND MAGNESITE.

SURVEY PUBLICATIONS ON LIME AND MAGNESITE.

In addition to the papers listed below, which deal principally with lime, magnesite, etc., further references on limestones will be found in the lists given under the heads "Cement" and "Building stone." These publications, except the one to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BASTIN, E. S. The lime industry of Knox County, Me. In Bulletin No. 285, pp. 393–400. 1906. 60c.

BUTTS, C. Limestone and dolomite in the Birmingham district, Alabama. In Bulletin No. 315, pp. 247–255. 1907.

BUTTS, C., BURCHARD, E. F., and ECKEL, E. C. Iron ores, fuels, and fluxes, of the Birmingham district, Alabama. (In preparation.)

CALKINS, F. C., and MACDONALD, D. F. A geologic reconnaissance in northern Idaho and northwestern Montana. (In preparation.)

ECKEL, E. C. Lime and sand-lime brick. In Mineral Resources U. S. for 1907, pp. 545–551. pt. 2. 1908.

HESS, F. L. Some magnesite deposits of California. In Bulletin No. 285, pp. 385–392. 1906. 60c.

——— The magnesite deposits of California. Bulletin No. 355. 1908.

MACDONALD, D. F. (See Calkins, F. C., and MacDonald, D. F.)

RIES, H. The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut. In Seventeenth Ann. Rept., pt. 3, pp. 795–811. 1896.

STOSE, G. W. Pure limestone in Berkeley County, W. Va. In Bulletin No. 225, pp. 516–517. 1904. 35c.

YALE, C. G. Magnesite deposits in California. In Mineral Resources U. S. for 1903, pp. 1131–1135. 1904. 70c.

——— Magnesite. In Mineral Resources U. S. for 1906, pp. 1145–1147. 1907. 50c.

——— Magnesite. In Mineral Resources U. S. for 1907, pp. 737–740. pt. 2. 1908. $1.

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GYPSUM AND PLASTERS.

SURVEY PUBLICATIONS ON GYPSUM AND PLASTERS.

The more important publications of the United States Geological Survey on gypsum and plasters are included in the following list. These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

ADAMS, G. I., and others. Gypsum deposits of the United States. Bulletin No. 223. 123 pp. 1904. 25c.

BOUTWELL, J. M. Rock gypsum at Nephi, Utah. In Bulletin No. 225, pp. 483–487. 1904. 35c.

BURCHARD, E. F. Gypsum and gypsum products. In Mineral Resources U. S. for 1906, pp. 1069–1078. 1907. 50c.

——— Gypsum. In Mineral Resources U. S. for 1907, pp. 643–650, pt. 2. 1908.

DARTON, N. H., and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming; a preliminary report. Bulletin No. 364. 1909.

ECKEL, E. C. Salt and gypsum deposits of southwestern Virginia. In Bulletin No. 213, pp. 406–416. 1903. 25c.

——— Gypsum and gypsum products. In Mineral Resources U. S. for 1905, pp. 1105–1115. 1906. $1.

HESS, F. L. A reconnaissance of the gypsum deposits of California. (In preparation.)

ORTON, E. Gypsum or land plaster in Ohio. In Mineral Resources U. S. for 1887, pp. 506–601. 1888. 50c.

RICHARDSON, G. B. Salt, gypsum, and petroleum in trans-Pecos Texas. In Bulletin No. 260, pp. 573–585. 1905. 40c.

SHALER, M. K. Gypsum in northwestern New Mexico. In Bulletin No. 315, pp. 260–265. 1907.

SIEBENTHAL, C. E. Gypsum of the Uncompahgre region, Colorado. In Bulletin No. 285, pp. 401–403. 1906. 60c.

——— Gypsum deposits of the Laramie district, Wyoming. In Bulletin No. 285, pp. 404–405. 1906. 60c.

——— (See also Darton, N. H., and Siebenthal, C. E.)

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GLASS SAND, ETC.

SURVEY PUBLICATIONS ON GLASS SAND AND GLASS-MAKING MATERIALS.

The list below includes the important publications of the United States Geological Survey on glass sand and glass-making materials. These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BURCHARD, E. F. Requirements of sand and limestone for glass making. In Bulletin No. 285, pp. 452–458. 1906.

——— Glass sand of the middle Mississippi basin. In Bulletin No. 285, pp. 459–472. 1906.

——— Glass-sand industry of Indiana, Kentucky, and Ohio. In Bulletin No. 315, pp. 361–376. 1907.

——— Notes on glass sands from various localities, mainly undeveloped. In Bulletin No. 315, pp. 377–382. 1907.

——— Glass sand, sand, and gravel. In Mineral Resources U. S. for 1906, pp. 993–1000. 1907. 50c.

——— Sand and gravel. In Mineral Resources U. S. for 1907, pt. 2, pp. 553–556. 1908.

CAMPBELL, M. R. Description of the Brownsville-Connellsville quadrangles, Pennsylvania. Geologic Atlas U. S., folio 94, p. 19. 1903.

COONS, A. T. Glass sand. In Mineral Resources U. S. for 1902, pp. 1007–1015. 1904.

STOSE, G. W. Glass-sand industry in eastern West Virginia. In Bulletin No. 285, pp. 473–475. 1906.

WEEKS, J. D. Glass materials. In Mineral Resources U. S. for 1883–1884, pp. 958–973. 1885. 60c.

——— Glass materials. In Mineral Resources U. S. for 1885, pp. 544–555. 1886. 40c.

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ABRASIVES.

SURVEY PUBLICATIONS ON ABRASIVE MATERIALS, QUARTZ, FELDSPAR, ETC.

The following list includes a number of papers, published by the United States Geological Survey or by members of its staff, dealing with various abrasive materials. The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The one marked "Exhausted" is not available for distribution, but may be seen at the larger libraries of the country.

ANDERSON, ROBERT. (See Arnold, Ralph, and Anderson, Robert.)

ARNOLD, RALPH, and ANDERSON, ROBERT. Diatomaceous deposits of northern Santa Barbara County, Cal. In Bulletin No. 315, pp. 438–447. 1907.

BASTIN, E. S. Feldspar and quartz deposits of Maine. In Bulletin No. 315, pp. 383–393. 1907.

——— Feldspar and quartz deposits of southeastern New York. In Bulletin No. 315, pp. 394–399. 1907.

——— Quartz (flint) and feldspar. In Mineral Resources U. S. for 1906, pp. 1253–1270. 1907. 50c.

——— Quartz and feldspar. In Mineral Resources U. S. for 1907, pt. 2, pp. 843–872. 1908.

CHATARD, T. M. Corundum and emery. In Mineral Resources U. S. for 1883–84, pp. 714–720. 1885. 60c.

ECKEL, E. C. The emery deposits of Westchester County, N. Y. In Mineral Industry, vol. 9, pp. 15–17. 1901.

FULLER, M. L. Crushed quartz and its source. In Stone, vol. 18, pp. 1–4. 1898.

GOLDING, W. Flint and feldspar. In Seventeenth Ann. Rept., pt. 3, pp. 838–841. 1896.

HIDDEN, W. E. The discovery of emeralds and hiddenite in North Carolina. In Mineral Resources U. S. for 1882, pp. 500–503. 1883. 50c.

HOLMES, J. A. Corundum deposits of the southern Appalachian region. In Seventeenth Ann. Rept., pt. 3, pp. 935–943. 1896.

JENKS, C. N. The manufacture and use of corundum. In Seventeenth Ann. Rept., pt. 3, pp. 943–947. 1896.

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MESLER, R. D. (See Siebenthal, C. E., and Mesler, R. D.)

PARKER, E. W. Abrasive materials. In Nineteenth Ann. Rept., pt. 6, pp. 515–533. 1898.

PHALEN, W. C. Abrasive materials. In Mineral Resources U. S. for 1907, pt. 2, pp. 607–626. 1908. $1.

PRATT, J. H. The occurrence and distribution of corundum in the United States, Bulletin No. 180. 98 pp. 1901. Exhausted.

——— Corundum and its occurrence and distribution in the United States. Bulletin No. 269. 175 pp. 1905. (Bulletin No. 269 is a later and revised edition of Bulletin No. 180.)

RABORG, W. A. Buhrstones. In Mineral Resources U. S. for 1886, pp. 581–582. 1887. 50c.

——— Grindstones. In Mineral Resources U. S. for 1886, pp. 582–585. 1887. 50c.

——— Corundum. In Mineral Resources U. S. for 1886, pp. 585–586. 1887. 50c.

READ, M. C. Berea grit. In Mineral Resources U. S. for 1882, pp. 478–479. 1883. 50c.

SIEBENTHAL, C. E., and MESLER, R. D. Tripoli deposits near Seneca, Mo. In Bulletin No. 340, pp. 429–437. 1908.

STERRETT, D. B. Abrasive materials. In Mineral Resources U. S. for 1906, pp. 1043–1054. 1907. 50c.

TURNER, G. M. Novaculite. In Mineral Resources U. S. for 1885, pp. 433–436. 1886. 40c.

——— Novaculites and other whetstones. In Mineral Resources U. S. for 1886, pp. 589–594. 1887. 50c.

WOOLSEY, L. H. Volcanic ash near Durango, Colo. In Bulletin No. 285, pp. 476–479. 1906.

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MINERAL PAINT.

SURVEY PUBLICATIONS ON MINERAL PAINT.

The following publications, except the one to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BURCHARD, E. F. Southern red hematite as an ingredient of metallic paint. In Bulletin No. 315, pp. 430–434. 1907.

——— Mineral Paints. In Mineral Resources U. S. for 1907, pt. 2, pp. 697–709.

ECKEL, E. C. The mineral paint ores of Lehigh Gap, Pennsylvania. In Bulletin No. 315, pp. 435–437. 1907.

——— Metallic paints of the Lehigh Gap district, Pennsylvania. In Mineral Resources U. S. for 1906, pp. 1120–1122. 1907. 50c.

——— (See also Hayes, C. W., and Eckel, E. C.)

HAYES, C. W., and ECKEL, E. C. Occurrence and development of ocher deposits in the Cartersville district, Georgia. In Bulletin No. 213, pp. 427–432. 1903. 25c.

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PHOSPHATES.

SURVEY PUBLICATIONS ON PHOSPHATES AND OTHER MINERAL FERTILIZERS.

The following papers relating to phosphates, gypsum (land plaster), and other mineral materials used as fertilizers have been published by the United States Geological Survey or by members of its staff. Further references will be found under the head of "Gypsum."

The United States publications, except those to which a price is affixed, may be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Those marked "Exhausted" are not available for distribution, but may be seen at the larger libraries of the country.

ADAMS, G. I., and others. Gypsum deposits in the United States. Bulletin No. 223. 127 pp. 1904. 25c.

DARTON, N. H. Notes on the geology of the Florida phosphates. In Am. Jour. Sci., 3d ser., vol. 41, pp. 102–105. 1891.

DARTON, N. H., and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming; a preliminary report. Bulletin No. 364. 1909.

ECKEL, E. C. Recently discovered extension of Tennessee white-phosphate field. In Mineral Resources U. S. for 1900, pp. 812–813. 1901. 70c.

——— Utilization of iron and steel slags. In Bulletin No. 213, pp. 221–231. 1903. 25c.

——— The white phosphates of Decatur County, Tenn. In Bulletin No. 213, pp. 424–425. 1903. 25c.

ELDRIDGE, G. H. A preliminary sketch of the phosphates of Florida. In Trans. Am. Inst. Min. Eng., vol. 21, pp. 196–231. 1893.

FERRIER, W. F. (See Weeks, F. B., and Ferrier, W. F.)

HAYES, C. W. The Tennessee phosphates. In Sixteenth Ann. Rept., pt. 4, pp. 610–630. 1895. $1.20.

——— The Tennessee phosphates. In Seventeenth Ann. Rept., pt. 2, pp. 1–38. 1896. $2.35.

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HAYES, C. W. The white phosphates of Tennessee. In Trans. Am. Inst. Min. Eng., vol. 25, pp. 19–28. 1896.

——— A brief reconnaissance of the Tennessee phosphate field. In Twentieth Ann. Rept., pt. 6, pp. 633–638. 1899.

——— The geological relations of the Tennessee brown phosphates. In Science, vol. 12, p. 1005. 1900.

HAYES, C. W. Tennessee white phosphate. In Twenty-first Ann. Rept., pt. 3, pp. 473–485. 1901.

——— Origin and extent of the Tennessee white phosphates. In Bulletin No. 213, pp. 418–423. 1903. 25c.

HESS, F. L. A reconnaissance of the gypsum deposits of California. (In preparation.)

IHLSENG, M. C. A phosphate prospect in Pennsylvania. In Seventeenth Ann. Rept., pt. 3, pp. 955–957. 1896.

MEMMINGER, C. G. Commercial development of the Tennessee phosphates. In Sixteenth Ann. Rept., pt. 4, pp. 631–635. 1895. $1.20.

MOSES, O. A. The phosphate deposits of South Carolina. In Mineral Resources U. S. for 1882, pp. 504–521. 1883. 50c.

ORTON, E. Gypsum or land plaster in Ohio. In Mineral Resources U. S. for 1887, pp. 596–601. 1888. 50c.

PENROSE, R. A. F. Nature and origin of deposits of phosphate of lime. Bulletin No. 46. 143 pp. 1888. Exhausted.

PURDUE, A. H. Developed phosphate deposits of northern Arkansas. In Bulletin No. 315, pp. 463–473. 1907.

SIEBENTHAL, C. E. (See Darton, N. H., and Siebenthal, C. E.)

STOSE, G. W. Phosphorus ore at Mount Holly Springs, Pennsylvania. In Bulletin No. 315, pp. 474–483. 1907.

——— Phosphorus. In Mineral Resources U. S. for 1906, pp. 1084–1090. 1907. 50c.

STUBBS, W. C. Phosphates of Alabama. In Mineral Resources U. S. for 1883–84, pp. 794–803. 1885. 60c.

VAN HORN, F. B. Phosphate rock. In Mineral Resources U. S. for 1907, pt. 2, pp. 651–657. 1908.

WEEKS, F. B. Phosphate deposits in the western United States. In Bulletin No. 340, pp. 441–447. 1908.

WEEKS, F. B., and FERRIER, W. F. Phosphate deposits in western United States. In Bulletin No. 315, pp. 449–462. 1907.

WILBER, F. A. Greensand marls in the United States. In Mineral Resources U. S. for 1882, pp. 522–526. 1883. 50c.

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SALINES.

SODIUM SULPHATE IN SODA LAKE, CARRISO PLAIN, SAN LUIS OBISPO COUNTY, CALIFORNIA.

By RALPH ARNOLD and H. R. JOHNSON.

INTRODUCTION.

The deposits of sodium sulphate described in this paper are found in the lowest portion of the Carriso Plain, which extends along and within the northeast boundary of San Luis Obispo County, Cal. The lake known locally as Soda Lake, or Salt Lake, in the bed of which this salt occurs, lies wholly within T. 31 S., R. 19 E., and T. 31 S., R. 20 E., and is about 12 to 15 miles west-southwest of McKittrick, Kern County, the nearest railroad station. Soda Lake receives the drainage from the Carriso Plain and the adjoining flanks of the bounding ranges, the total catchment basin being somewhat over 525 square miles in extent. The lake has a length of about 5 miles and a maximum width of a little over a mile, and includes an area of nearly 3,000 acres. It remains practically dry except in extraordinarily wet seasons. The region in which the deposits occur is of the arid type characteristic of the intermontane valleys of California away from the coast. The Carriso Plain has a length of about 40 miles and an average width of 12 or 15 miles and extends parallel to the inclosing mountains—the Caliente Range on the southwest and the Temblor Range on the northeast. The lowest point in the plain lies at an elevation of about 1,925 feet above sea level.

Rainfall records for this region are not available, but the precipitation is probably about the same as that of the west side of the San Joaquin Valley—between 5 and 10 inches annually. No axial stream flows through the Carriso Plain, although numerous small gulches and canyons, whose mouths debouch upon the gravelly slopes of its margin, enter from both sides. The nearest running stream in the region is San Juan River, which flows northwestward in a deep gorge parallel to the Carriso Plain but lying outside of its drainage area, in the Caliente Range to the southwest.

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OCCURRENCE.

Geologic statement.—The Carriso Plain is a structural depression which has been faulted down between the Caliente and Temblor ranges and has been sufficiently covered by Pleistocene and possibly earlier débris to mask its real character. Faults, some of them very recent geologically, bound the plain along its northeast and southwest margins. The amount of folding and faulting which has taken place in this region is very great. This intense deformation has, in conjunction with denudation, exposed large areas of soft conglomerate, sandstone, and shale, particularly in the adjacent ranges, to the solvent action of rain, and thus through the agency of running water the soluble salts of these rocks have been transferred, in part, to the lowest portion of the plain. There they have been deposited, through evaporation of the solvent, in a series of saline beds, the chief constituent of which is sodium sulphate.

Chemical nature.—A sample of this salt collected at the surface of the lake, just west of the present evaporation plant, which is in sec. 19, T. 31 S., R. 20 E., varies from dull to lustrous pure white in color and, though more or less grainy, may be easily crushed between the fingers. An analysis of the salt, made by George Steiger in the laboratory of the United States Geological Survey, is as follows:

Analysis of salt crust from Soda Lake.

Insoluble	0.40
Al_2O_3	.04
MgO	1.66
CaO	.45
Na_2O	40.50
K_2O	.28
H_2O-, H_2O+	3.65
CO_2	None.
SO_3	46.12
Cl	9.27
	102.37
Less oxygen	2.09
	100.28

The two analyses below were made by Thomas Price & Son, of San Francisco, the first in October, 1904, and the second in November, 1905.

Analysis of sodium sulphate crystals from Soda Lake.

Anhydrous sodium sulphate	42.78
Sodium chloride	.32
Water	56.90
	100.00

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Analysis of dried sample crust from top of Soda Lake.

Insoluble matter	0.16
Sodium sulphate	98.65
Sodium chloride	.47
Magnesium sulphate	.43
Loss and undetermined	.29
	100.00

It is stated that tests indicate that the surficial deposit of this salt is from 1 to 6 feet in depth and is underlain by a supersaturated solution of the sulphate and water.

COMMERCIAL DEVELOPMENT.

The deposit offers an almost unlimited supply of the mixed salts and its profitable exploitation is dependent almost entirely on transportation facilities, which at present are inadequate. The developing company owns traction engines with which it expects to haul the product to the most available railroad point, presumably Hazelton, near the terminus of the Sunset branch of the Southern Pacific Railroad, 32 miles to the southeast and 1,200 feet lower than the lake. The McKittrick branch of the same railroad lies only about 15 miles distant, but the Temblor Range, which must be crossed in making the trip, presents a considerable obstacle. With the construction of a contemplated railroad to San Luis Obispo by way of the Carriso Plain the commercial development of this deposit will be greatly assisted.

The exploitation of this deposit has been undertaken by the Carisa Chemical Company, which is incorporated under the laws of California with a capital of $1,000,000. It is stated that about $60,000 has been expended for machinery and other equipment for the extraction of the sodium sulphate, but at the time the plant was visited in September, 1908, operations had been temporarily suspended.

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SURVEY PUBLICATIONS ON SALINES, INCLUDING SALT, BORAX, AND SODA.

The more important publications of the United States Geological Survey on the natural lime, sodium, and potassium salts included in this group are those listed below.

These publications, except those to which a price is affixed, may be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

CAMPBELL, M. R. Reconnaissance of the borax deposits of Death Valley and Mohave Desert. Bulletin No. 200. 23 pp. 1902. 5c.

——— Borax deposits of eastern California. In Bulletin No. 213, pp. 401–405. 1903. 25c.

CHATARD, T. M. Salt-making processes in the United States. In Seventh Ann. Rept., pp. 491–535. 1888.

DARTON, N. H. Zuñi salt deposits, New Mexico. In Bulletin No. 260, pp. 565–566. 1905. 40c.

DAY, W. C. Potassium salts. In Mineral Resources U. S. for 1887, pp. 628–650. 1888.

——— Sodium salts. In Mineral Resources U. S. for 1887, pp. 651–658. 1888.

ECKEL, E. C. Salt and gypsum deposits of southwestern Virginia. In Bulletin No. 213, pp. 406–416. 1903. 25c.

——— Salt industry of Utah and California. In Bulletin No. 225, pp. 488–495. 1904. 35c.

HILGARD, E. W. The salines of Louisiana. In Mineral Resources U. S. for 1882, pp. 554–565. 1883.

KINDLE, E. M. Salt resources of the Watkins Glen district, New York. In Bulletin No. 260, pp. 567–572. 1905. 40c.

PACKARD, R. L. Natural sodium salts. In Mineral Resources U. S. for 1893, pp. 728–738. 1894.

PHALEN, W. C. Salt and bromine. In Mineral Resources U. S. for 1907, pt. 2, pp. 659–672. 1908.

RICHARDSON, G. B. Salt, gypsum, and petroleum in trans-Pecos Texas. In Bulletin No. 260, pp. 573–585. 1905. 40c.

YALE, C. G. Borax. In Mineral Resources U. S. for 1889–1890, pp. 494–506. 1902.

——— Borax. In Mineral Resources U. S. for 1906, pp. 1059–1062. 1907.

——— Borax. In Mineral Resources U. S. for 1907, pt. 2, pp. 631–635. 1908.

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SULPHUR AND PYRITE.

SULPHUR DEPOSITS NEAR THERMOPOLIS, WYO.

By E. G. Woodruff.

INTRODUCTION.

The paper here presented treats of the deposits of sulphur near Thermopolis, Wyo., and describes the processes of mining and refining the ore. The data on which the report is based were collected in the fall of 1908. Previous to that time several writers had described the general geology of the area, but when they visited the region the sulphur deposits had not been explored and their extent was unknown. The first of these writers was George H. Eldridge,[a] who mentions the hot springs and travertine deposits. More recently these springs and the geologic conditions which are thought to give rise to them have been discussed by N. H. Darton[b] and C. A. Fisher,[c] who have also described the geology of the region.

Recent exploration of the sulphur beds by prospect pits and drill holes has offered an opportunity to study the deposits and the conditions which control their deposition. The information gained by this investigation is presented in the following pages in the hope that it may lead to the discovery of deposits now unknown and at the same time prevent needless expenditure of money in prospecting barren ground.

LOCATION AND EXTENT.

The sulphur deposits are located 3½ miles northwest of Thermopolis, Wyo., on the gentle northeast slope of a small eroded anticline adjacent to the valley of Owl Creek, in sec. 21, T. 43 N., R. 95 W. A large number of drill holes put down in this area by the Wyoming

[a] A geological reconnaissance in northwest Wyoming: Bull. U. S. Geol. Survey No. 119, 1894, p. 67.

[b] The hot springs at Thermopolis, Wyo.: Jour. Geology, vol. 14, 1906, p. 194; Geology of the Owl Creek Mountains, 59th Cong., 1st sess., Senate Doc. No. 219, 1906, p. 39.

[c] Geology and water resources of the Bighorn Basin, Wyoming: Prof. Paper U. S. Geol. Survey, No. 53, 1906, p. 62.

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Sulphur Company have found the deposits of sulphur in a zone about one-eighth of a mile in width and one-fourth of a mile in length, along the base of the anticline, to the northeast of a timber-covered limestone ridge. A thorough prospecting of all of the territory in which the geologic conditions are favorable has not been undertaken, but it is believed that the sulphur-bearing zone extends for a considerable distance, possibly one-half mile, to the northwest and a slightly greater distance to the southeast, beyond the limits of the proved ground. One condition that is considered to point to the presence of sulphur within the area outlined above is the occurrence of deposits of travertine upon beds of altered limestone. This association of travertine and limestone seems to be necessary to the deposition of sulphur; travertine alone contains only small particles of the mineral.

SURFACE FEATURES.

Viewed from the crest of the Owl Creek Mountains, the surface of the region consists of a long, gentle northeast slope trenched from top to bottom by many small gulches and terminated to the east by the deep canyon of Bighorn River. This slope merges at its outer margin into a dissected red-beds plain across which the river meanders in a valley bordered by narrow flood plains. Into this valley a few steep-sided ravines enter from the west. The plain in turn is limited on the north by a moderately steep-sided, partly tree-clad limestone ridge, which extends northwestward from Thermopolis, where it is cut transversely by a small canyon of Bighorn River. Remnants of travertine deposits form a mesa at one place on the crest of the ridge and occur in small terraces at various levels along the sides. To the north a plain slopes from the base of this ridge to the valley of Owl Creek.

GEOLOGIC RELATIONS.

Paleozoic rocks arch the summit of the Owl Creek Mountains 3,000 feet above the surrounding plains, and occupy the surface on the north slope. They pass beneath the red beds at the base of the mountains, and again come to view in a small area along the crest of the ridge northwest of Thermopolis, where the rocks are sharply folded into an anticline partly covered by travertine deposits. A section of all the older sediments is exposed in the walls of the Bighorn Canyon. Here the Cambrian conglomerates, shales, and limestones rest upon granites; above the Cambrian rocks are the massive Ordovician Bighorn limestone and Mississippian Madison limestone; these in turn are covered by red shales of the Amsden formation (thought to be of Pennsylvanian age); and the massive Tensleep sandstone and the cherty Embar limestone (both of Pennsylvanian age) occupy the

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top of the Paleozoic column. Softer Mesozoic rocks have been eroded from the mountains, but remain around the base, where the Chugwater formation (Triassic or Permian?) which occupies the lowest part, is overlain by Jurassic limestones and Cretaceous shales and sandstones. Hot-spring deposits and alluvium rest unconformably upon the upturned and eroded edges of upper Paleozoic and lower Mesozoic rocks. Previous to the present examination no observer has recorded the presence of igneous rocks in the area, though their probable presence was suggested by Darton[a] in 1906. During an examination of the region here discussed two small masses of rock thought to be igneous intrusions were noted in exposures of upturned Upper Cretaceous rocks in an escarpment 2 miles northeast of the sulphur mines and 2½ miles north of the springs at Thermopolis. These supposed igneous rocks occupy an area too small to show their true relation to the structure of the stratified beds. It is believed, however, that they connect below with much larger bodies of igneous rock.

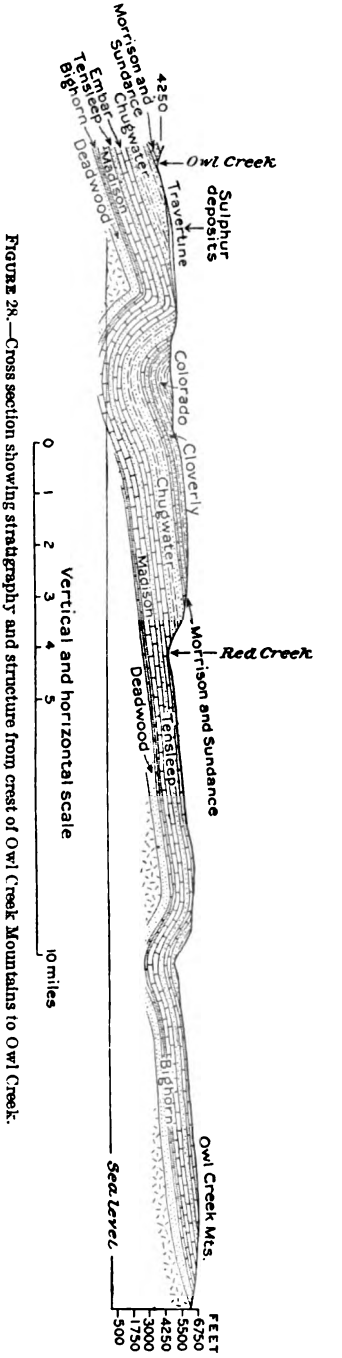

FIGURE 28.—Cross section showing stratigraphy and structure from crest of Owl Creek Mountains to Owl Creek.

STRUCTURE.

The surface rocks of the region show that the beds have a moderate dip from the crest of the Owl Creek Mountains northeastward into the interior of the Bighorn Basin. The uniformity of the major structure, however, is interrupted by two minor undulations that parallel the mountain uplift. One of these is a slight fold on the mountain slope and the other forms a sharp unsymmetrical anticline, which gives rise to the high ridge trending northwestward from Thermopolis. The structure is shown by figure 28, which represents a cross section of the beds from the crest of the moun-

[a] Darton, N. H., The hot springs at Thermopolis, Wyo.: Jour. Geology, vol. 14, 1906, p. 200.

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tains northeastward to the valley of Owl Creek. The rocks in this small anticline have been sharply folded and probably sufficiently fractured along the crest to form passages, through which the heated water escapes to the surface.

HOT SPRINGS.

At the present time one mammoth hot spring and several small ones are discharging their water into Bighorn River near Thermopolis, at a rate estimated to be 3,000 to 4,000 gallons a minute. The water issues from the large spring at a temperature of 135° F. The odor of hydrogen sulphide is strong about the spring and the quantity of carbon dioxide escaping indicates that the water is saturated with that gas also. An analysis has shown potassium, sodium, magnesium, calcium, and iron salts in large quantities. These salts are deposited when the water spreads out and cools, and in this way the terraces are built up.

Though the springs are now building their terraces rapidly, there is evidence that they have had a long period of activity and that they have been distributed over several square miles, as extinct cones and terraces along the river show a wider distribution at about the present level. The earlier positions of the springs are indicated by the terraces at various levels along the side and crest of the anticline. One bed of travertine caps a mesa 3 miles northwest of Thermopolis and 700 feet higher than the mammoth spring. This does not indicate, however, that the travertine is 700 feet thick at any one point, but that there has been continuous deposition while the streams of the region have lowered their channels that amount. Although the travertine is not thick its distribution is rather widespread, as is shown by remnants of terraces over an area of several square miles. It is most extensive adjacent to Bighorn River, but occurs at short intervals on the crest and slopes of the anticline between the river and Owl Creek. The remnants of the travertine are too few and scattered to determine with precision the previous extent of these beds or their greatest thickness. The first springs seem to have been situated at the crest of the anticline, about 3 miles northwest of Thermopolis; since they began to issue there has been a gradual progression toward the present site on Bighorn River, the springs probably following the stream in its meandering and downward cutting. To the west, however, there seem to have been two periods of activity, one along the crest of the anticline and another, of later date, during which the travertine and sulphur were deposited along the base of the uplift.

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TRAVERTINE AND SULPHUR.

NATURE AND OCCURRENCE.

The travertine is composed in part of carbonate of lime and in part of sulphate of lime in small crystals of the mineral selenite, which seems to be an alteration product due to the action of the sulphur waters. It occurs in small irregular plates formed by the evaporation of the water on plane surfaces or in fibers when deposited about the threads of algæ, which are abundant in the thermal waters. The travertine generally contains some native sulphur in isolated crystals or small nodules, but the quantity of the mineral is too small to be extracted with profit. The minable sulphur deposits occur in the altered Embar limestone which lies immediately below the travertine and through which the sulphur-bearing waters passed in their course to the surface. The sulphur seems to be present in very irregular deposits or pockets about the sites of extinct springs, where the sulphur-bearing water came into contact with the limestone. Few if any of these deposits exceed 100 feet in horizontal diameter; their depth is uncertain, but probably the beds do not connect with large deep-seated masses. One drill hole is reported to have passed through 30 feet of barren rock before entering the ore, and then to have continued for 15 feet in the mineral without reaching its base. There is no uniformity in the shape, size, or arrangement of these ore-bearing pockets. In general they occur in groups where the sulphur-bearing waters found passage to the surface through a number of vents. The number and arrangement of these pockets in the groups depend, therefore, on varying subterranean conditions which can not be determined from a surface investigation.

The cross section (fig. 28) shows the relation of the travertine and sulphur to the structure of the region.

Native sulphur in this district occurs in two forms—in small yellow crystals filling veins or cavities in the rocks, and in a massive form where the original structure of the limestone is retained, but where the calcium carbonate is replaced by the sulphur. The sulphur is found in crevices, channels, or cavities such as water courses make where they traverse limestone beds. The cavities seem to be portions of subterranean channels through which the hot sulphur-bearing waters flowed and on the walls of which the sulphur was gradually deposited until the chambers were completely filled or, in some places, only partly filled before the passage was stopped at some point and the water diverted to other channels. As previously stated, no regular arrangement of the cavities can be discovered, though they seem to occur in groups at places where the water found free passage. In the areas between the groups of cavities only a small amount of

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sulphur is present, but in the enriched pockets the amount reaches 30 to 50 per cent of the rock or even more, and becomes commercially important. Some of these abandoned water courses are arranged in a close network with the interspaces so completely mineralized that the whole area is now a mass of sulphur, but in general the channels lie close together near the site of the extinct spring and farther apart away from the old vent. Laterally a deposit may be rich at one point and barren 10 feet away. The sulphur ore thus varies from a low percentage associated with barren rock to small masses of almost pure mineral, but as the deposits follow no general laws, all of the area where geologic conditions are favorable must be tested to locate the sulphur beds.

ORIGIN OF THE SULPHUR ORE.

The presence of sulphur in the water now issuing from the hot springs at Thermopolis, 3½ miles from the mines, and the fact that the mineral occurs chiefly in channels such as water forms when it flows through limestone are considered to indicate deposition by hot springs. Further evidence is afforded by the discovery of the best deposits of sulphur at the sites of extinct springs, where they issued from the limestone. A consideration of the geologic conditions surrounding these deposits seems to show that the water enters the strata on the slopes of the Owl Creek Mountains to the south and passes downward along some permeable stratum, probably the Tensleep sandstone, to the bottom of the syncline, rises in the anticline, and finds escape at the top through fractures in the sharply folded beds. In such a simple passage of the water there is nothing to account for the temperature of 135° in the present springs, or for the sulphur the water contains. Inasmuch as dikes of igneous rock intrude strata much higher than those from which the water discharges, and only 2½ miles away, it is supposed that larger bodies of uncooled igneous rock lie sufficiently close to the surface to furnish both heat and sulphur to the water which percolates through them. Chemical reactions concerned in the liberation of the sulphur and other minerals probably add slightly to the heat otherwise obtained, but this action alone could not maintain the water at the high temperature it possesses.

The chemical conditions which are supposed to be concerned in the deposition of sulphur in hot springs have been previously discussed.[a]

A comparison of the sulphur deposits at Cody and Thermopolis shows that both occur in altered Embar limestone about the seat of former hot springs, in crevices, cavities, and channels associated with gypsum, the deposits being also near active hot springs and adjacent

[a] Woodruff, E. G., Sulphur deposits at Cody, Wyo.: Bull. U. S. Geol. Survey No. 340, 1908, p. 454.

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to an anticline. They are so similar even in minor details that the conditions which caused the deposition of sulphur at one place must have acted to produce a similar result at the other. The association of considerable sulphur only with altered limestone is more clearly shown in the sulphur deposits near Thermopolis than in those at Cody.

As stated in the earlier publication, it is believed that the cause which produces the heat also frees the sulphur and permits it to come to the surface, but the real cause can only be conjectured. As the waters ascend through the rocks the sulphur compounds are cooled and oxidized and part of the mineral is deposited. Both oxidation and loss of heat can best take place near the surface; hence the deposits formed in this way are probably shallow. It is of interest also to note that the ore is associated chiefly with calcareous and not with siliceous rocks, though the solutions must have traversed sandstone beds in their passage from below. This fact is believed to indicate that limestone is essential to the precipitation of the sulphur from solution, though it renders more difficult the explanation of the absence of sulphur in the travertine. It is thought, therefore, that deposits of sulphur large enough to be mined will be found only near the surface and in beds of altered limestone. All the essential conditions mentioned above are operative in the area here described. Hot springs are active, limestone is abundant, and the hot water holds H_2S and CO_2 in solution.

MINING, SMELTING, AND MARKETING.

The Wyoming Sulphur Company, of Thermopolis, Wyo., the only company operating in the area at the present time, began development in the fall of 1908. Mining is carried on in open-pit quarries, in which promising places are located, small drill holes are put down to prove the ground, the surface rock is removed from favorable sites, and the rock and ore are extracted by drilling and blasting. The rock is then broken to convenient size and sorted by hand, and all ore estimated to contain sufficient sulphur for treatment is hauled by wagon to the reduction works, one-fourth of a mile distant. At the smelter the ore is placed in bins, from which it is discharged into small steel cars with perforated sides, each holding about two tons. A string of three cars is then run into a large cylindrical retort, the door closed, and steam admitted at 60 pounds pressure for two hours. The sulphur is melted and flows to the bottom of the retorts, from which it escapes through a trap into bins, where it is allowed to cool. When the sulphur has been melted the cars containing the gangue are removed from the retort, other cars are admitted, and the process is repeated. This process is not considered highly efficient, as only about two-thirds of the sulphur which the rock contains is melted

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out; the remainder is lost in the refuse. After the sulphur is cooled it is crushed in an 8-inch Blake crusher and pulverized to an impalpable powder in a rotary grinder. It is then sacked and taken to Crosby, 8 miles distant, for shipment to various points in Wyoming and adjoining States.

PRODUCTION.

The plant now installed has a capacity of 20 tons a day, but has not yet been operated to the full capacity. According to a statement of the superintendent of the company on December 15, 1908, the plant had produced up to that time 200 tons of sulphur and was then yielding 10 tons a day. The demand for ground sulphur is reported to be fairly good at $35 a ton at destination.

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SURVEY PUBLICATIONS ON SULPHUR AND PYRITE.

The list below includes the important publications of the United States Geological Survey on sulphur and pyrite.

These publications, except those to which a price is affixed, may be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

ADAMS, G. I. The Rabbit Hole sulphur mines, near Humboldt House, Nev. In Bulletin No. 225, pp. 497–500. 1904. 35c.

DAVIS, H. J. Pyrites. In Mineral Resources U. S. for 1885, pp. 501–517. 1886. 40c.

ECKEL, E. C. Gold and pyrite deposits of the Dahlonega district, Georgia. In Bulletin No. 213, pp. 57–63. 1903. 25c.

——— Pyrite deposits of the eastern Adirondacks, N. Y. In Bulletin No. 260, pp. 587–588. 1905. 40c.

LEE, W. T. The Cove Creek sulphur beds, Utah. In Bulletin No. 315, pp. 485–489. 1907.

MARTIN, W. Pyrite. In Mineral Resources U. S. for 1883–84, pp. 877–905. 1886. 60c.

PHALEN, W. C. Sulphur and pyrite. In Mineral Resources U. S. for 1907, pt. 2, pp. 673–683. 1908.

RANSOME, F. L. Geology and ore deposits of Goldfield, Nev. Professional Paper No. 66. (In press.)

RICHARDSON, G. B. Native sulphur in El Paso County, Tex. In Bulletin No. 260, pp. 589–592. 1905. 40c.

ROTHWELL, R. P. Pyrites. In Mineral Resources U. S. for 1886, pp. 650–675. 1887. 50c.

SPURR, J. E. Alum deposit near Silver Peak, Esmeralda County, Nev. In Bulletin No. 225, pp. 501–502. 1904. 35c.

WOODRUFF, E. G. Sulphur deposits at Cody, Wyo. In Bulletin No. 340, pp. 451–456. 1908.

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MISCELLANEOUS NONMETALLIC PRODUCTS.

MICA DEPOSITS OF SOUTH DAKOTA.

By Douglas B. Sterrett.

INTRODUCTION.

The mica mines described in this paper are all located within a radius of 8 miles of Custer, S. Dak., in the southern part of the Black Hills. This area includes the better deposits of mica so far located, though some deposits occur 12 to 15 miles north of Custer, on the north side of Harney Peak. With the limited time available for examination it was not possible to visit all the mines, even of those around Custer. The field notes for the present article were obtained during the first part of August, 1908. At the time of visit there were but two mines in operation—the No. 1 or New York mine, and the No. 2 or White Spar mine, both of the Westinghouse Electric and Manufacturing Company. The writer is indebted to Mr. Joseph Pyne, superintendent for the Westinghouse Company, and to several citizens of Custer for making it possible to examine the mines described below.

Previous to 1906 the production of mica in South Dakota had been small for several years, being often only that obtained from assessment work on the claims, but in that year the Westinghouse Company took up several mines and prepared for systematic and extensive work. The success of this company has raised South Dakota to second rank among the mica-producing States. Of the 1,060,182 pounds of sheet and 3,025 tons of scrap mica, with a total value of $392,111, produced during 1907 in the United States, South Dakota contributed nearly a third. If some of the mines now idle or worked only in a desultory way could be equipped for operation on a large scale, the production of South Dakota would be largely increased. If the total production of mica in the United States could be increased nearly three times, the domestic demand could be satisfied with the domestic production, with the exception of the soft "amber" or phlogopite

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mica necessary in the manufacture of commutators for electric dynamos and motors. A quantity of this variety would still have to be imported from Canada, as there are no deposits known to be of value in the United States. It is probable that other consumers of mica could develop deposits in one or more of the mica regions of the United States and supply their own demands as the Westinghouse Company has done—that is, with the exception of the soft "amber" mica.

The commercial applications of mica are numerous. The principal use at the present day is in the manufacture of electric apparatus. In the early days of the industry in this country the chief demand for mica was for glazing purposes, principally in stove manufacture. This has now become one of the lesser uses, along with the manufacture of gas lamp chimneys, etc. The value of good sheet mica suitable for glazing is higher than that of the material suitable for electric purposes. The demand for glazing mica is insufficient to use all the sheet mica produced, so only the best quality and larger sheets are used for this purpose. "Micanite" or built-up mica board, for the manufacture of which much smaller sheets can be used, is an amply good substitute for large sheet mica in electric work.

Mica from one locality may have properties rendering it more suitable for certain applications than that from another, though not necessarily excluding it from other uses. Thus, the Canadian "amber" is especially adapted to commutator insulation; the best North Carolina "rum" colored, when in thick sheets, or "white" mica, when in thin sheets, is well suited for glazing. The South Dakota mica in general is a little softer and less clear than the North Carolina mica and therefore not so satisfactory for glazing. It is, however, well adapted to the manufacture of "micanite" and other products for use in electric machinery and apparatus.

GENERAL GEOLOGY.

The geology and mineral resources of the Black Hills have been described by numerous writers. Of the reports on geology those of Newton and Jenney[a] and of Darton,[b] taken together, furnish an excellent description. The mica resources have been treated in the South Dakota Geological Survey reports and have been mentioned in a number of the annual reports on the mineral resources of the United States published by the Federal Survey. A booklet with geologic map by Samuel Scott,[c] of Custer, S. Dak., serves as a useful guide to the general geology of the Black Hills.

[a] Newton, Henry, and Jenney, W. P., Geology and Resources of the Black Hills of Dakota: U. S. Geog. and Geol. Survey Rocky Mt. Region, 1880.

[b] Darton, N. H., Preliminary description of the geology and water resources of the southern Black Hills: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901.

[c] Rocks, minerals, and other resources of the Black Hills.

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The Black Hills are a group of mountains rising to a maximum elevation, in Harney Peak, of 7,240 feet above the sea, or 3,000 to 4,000 feet above the surrounding plains. They form an oval uplift about 125 miles long from north-northwest to south-southeast and 60 miles wide. The core of this uplift is composed of highly metamorphosed slates, gneisses, and schists with granitic intrusions. This core of ancient rocks is completely encircled by strata of later formations, which dip away from the core on all sides and were evidently once continuous over its top as a dome. The oldest of these strata flanking the core is a conglomerate and sandstone formation of Cambrian age, called Potsdam by Newton and Jenney and Deadwood by Darton. The Deadwood formation is overlain by other formations, among which are limestone of Carboniferous age, red beds and shale of Triassic (?) and Jurassic age, Upper and Lower Cretaceous sandstones, shales, and limestones, and Tertiary "badland" formations. These formations outcrop at successively greater distances from the central core of metamorphic rocks, and some of the outcrops form hogbacks with the scarp toward the center of the uplift.

Newton and Jenney call attention to a marked difference in the metamorphic rocks of the northeastern part of the area from those of the southwestern part. Those of the northeastern part are less metamorphosed and more nearly slates in texture and structure, while those of the southwestern part are highly metamorphic gneisses and schists, micaceous, chloritic, hornblendic, and quartzitic in composition. Newton and Jenney call the gneisses and schists "Older Archean" and the slates "New Archean." In a report on the Cretaceous formation of the Black Hills,[a] the northeastern metamorphic area is called Algonkian and the southwestern area Archean. Whatever the age of these formations, that in the southwestern part, in which the mica deposits occur, is composed of true gneisses and schists in which the mashing has been extreme and the development of metamorphic minerals extensive. In comparing typical specimens of the slates and mica slates of the northeastern area with the gneisses and schists of the southwestern area, the writer was impressed with the extreme difference in the degree of metamorphism they had undergone. Newton and Jenney state that granites occur only in the "Older Archean" rocks, and that granitic pebbles were found in the Cambrian conglomerate overlying them. They therefore conclude that the granite is pre-Cambrian and older than the slate formation. Whether all the granite can be included in this category it would not be safe to say.

The granite formation of the Black Hills has its greatest development around Harney Peak and southward to Custer. Other smaller

[a] Ward, L. F., Jenney, W. P., Fontaine, W. M., and Knowlton, F. H., Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1899, Pl. LIII.

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bodies and the pegmatites, into which it appears to grade in some places, occur in various parts of the highly metamorphic areas. Much of this granite has a very coarse texture and in some places it is difficult to know whether to classify the rock as granite or pegmatite. The pegmatite occurs both in the metamorphic rocks and in the granite. The prevailing trends of the gneisses and schists and of many of the inclosed pegmatites in the region of Custer is northwest to north. The dip is more variable, though in the many localities noted it was to the southwest or vertical. The gneisses and schists are much folded in places and are to some extent crinkled with minor folds.

OCCURRENCE OF MICA.

In the Black Hills as elsewhere muscovite mica of commercial value is found in pegmatite. In this rock mica occurs as an accessory mineral of more or less prominence, the essential constituents of pegmatite being feldspar and quartz. The feldspars are commonly orthoclase or microcline, though a plagioclase, albite, or oligoclase is present in some pegmatites, and locally plagioclase is the predominant feldspar. Pegmatites thus have the same constituent minerals as granites, though generally deficient in biotite and lacking in other accessory minerals, as hornblende or pyroxene. The proportions of the constituent minerals vary widely, not only in different bodies, but even in the same body. In some places the mass is chiefly feldspar with but small amounts of quartz and accessory minerals; in others quartz is the principal mineral. The deposits of mica-bearing pegmatites around Custer probably have a more uniform mixture of feldspar and quartz than many of those in North Carolina.

The occurrence of accessory minerals in the pegmatites of the Black Hills is variable. In several of the deposits north of Harney Peak large spodumene crystals, columbite, cassiterite, beryl, etc., have been found in some quantity. In the mica deposits near Custer these minerals are rare or confined to one or two occurrences. In nearly every one of the mines examined around Custer black tourmaline was found, and in many it was abundant in crystals of large size. J. A. Holmes[a] mentions this occurrence and contrasts it with the general scarceness of tourmaline in the tin-bearing pegmatites north of Harney Peak. On the same page it is stated that mica apparently is not found plentifully in commercial sizes in the pegmatites of the tin region. Around Custer, where the best mica deposits have been found, only one pegmatite in many carries sufficient mica to pay to work. Holmes[b] estimates that in some portions of the New York mine mica composes 10 per cent of the whole peg-

[a] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, continued, 1899, p. 699.
[b] Op. cit., p. 693.

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matite, but that in others it forms not more than 1 per cent. Figures given by Mr. Pyne, the present superintendent, show that the rough mica obtained along the walls of the pegmatite (the only portion worked for mica in this mine) amounts to 6 or 7 per cent. The interior of the pegmatite at this mine carries very little mica, say 0.5 per cent; this would give about 2.5 per cent of mica in the whole mass of pegmatite.

The texture of pegmatite may be like that of very coarse granite, sometimes called giant granite, or the individual minerals may be separated out into large masses in different positions in the pegmatite. These masses may be very irregular in shape or arranged in bands generally parallel with the walls, giving the mass a veinlike appearance, as in many of the mica "veins" of North Carolina.[a] The mica-bearing pegmatites around Custer show a tendency to have an evenly granular texture or irregular segregation of mineral masses rather than a banded structure. In much of the rock there is, however, a rough banded arrangement in the segregation of the mica crystals along one or both walls. This structure does not resemble that of a vein so much as where bands of a single mineral, as quartz or feldspar, occur. The crystals of feldspar and irregular masses of quartz may attain dimensions of several feet across in pegmatite.

The shape of pegmatite bodies is variable. Some are rather persistent in length and form dikelike or veinlike bands or sheets that can be traced for several hundred yards. Others are lenticular in shape and occur either in short, thick masses or in long, slender bodies. Many of the pegmatite masses are very irregular in shape and are very difficult to follow in mining. Some pegmatite bodies lie conformable with the schistosity of the inclosing gneiss or schist either through part or the whole of their extent; others cut across the bedding of the rock formations. In places the lenses or sheets follow the irregularities of the inclosing rock. In this way they may be interfolded with gneisses and schists, or bulge or elbow out abruptly. Pegmatites may range in thickness from less than an inch to many yards, and the lenses may vary in length from 2 to 20 or more times the thickness. The pegmatites observed around Custer exhibit many of the above described characters. Some occur in regular sheets whose outcrops can be traced for several hundred yards; others are typically lenticular. Some lie parallel with the schistosity of the inclosing rock and others cut across the rock. The general features of the pegmatites around Custer resemble those of dikes, the veinlike type being rare or absent.

[a] Sterrett, D. B., Mica deposits of western North Carolina: Bull. U. S. Geol. Survey No. 340, 1907, pp. 400–422.

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DESCRIPTION OF MINES.

No. 1 MINE.

The No. 1 mine of the Westinghouse Company, formerly called the New York mine, is 5¼ miles southwest of Custer, between Hay Creek and Fourmile Creek. The mine is in a small prominent hogback-like knob 700 feet long and about one-third as wide. This knob is nearly 200 feet higher than the level of Hay Creek on the southeast, and about 100 feet higher than the gentle slope from its base to the valley of Hay Creek.

The earlier work at the New York mine consisted of open cuts, inclines, and stopes, which extend in one place from the surface nearly to the present 100-foot level. The workings of the present company are systematic, and consist of a vertical shaft to the 200-foot level, with a 16-foot sump at the bottom and drifts with stopes on the 50-foot, 100-foot, and 200-foot levels. The mine is equipped with a 400-horsepower boiler and engine of Westinghouse make. Power is transmitted electrically from two 150-kilowatt generators. The mine is lighted with incandescent electric lights and the camp with arc lamps. The hoist, grinding plant, and shop are also operated by electric power. Air drills are used throughout the mine.

The country rock is biotite gneiss and schist striking northwesterly and dipping about 50° SW. The pegmatite is approximately conformable with the inclosing gneiss. The contact of the two is sharp, though with gentle rolls along the strike. The pegmatite has a thickness across the dip of about 30 feet at the surface, 25 feet on the 100-foot level, and 28 feet on the 200-foot level. The mica occurs in two streaks or "veins" in the pegmatite from 1 to 8 feet thick along each wall. The interior of the pegmatite is nearly barren of mica or too poor to pay for working. Although the mica streaks vary in thickness and richness they are unusually regular for mica "veins." Through the greater part of the mine opened up to the time of visit the veins were found sufficiently rich to pay for working, and in places the mica was very abundant. The mica crystals have a tendency to occur in flattened or tabular blocks lying perpendicular to the walls of the pegmatite, though without other definite orientation. The more common size of crystals range from 2 to 8 inches in diameter and from 1 to 5 inches in thickness. Crystals a foot in diameter are not rare while some measuring a yard across are found.

Figure 29 represents a generalized cross section of the pegmatite "veins" and workings at the New York mine. The first operations at this mine were influenced largely by the position of the outcrop of the pegmatite. This rock forms the top and southwest side of the knob in which the mine is located. The hanging wall lies near the surface of this side of the knob and was readily worked by open cuts.

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The foot wall of the pegmatite outcrops along the top of the knob. Besides numerous smaller openings on the outcrops, drifts have been run to the northwest on each " vein " on the 50-foot level. The entrance to the 50-foot level is made from an open cut on the outcrop of the vein about 50 feet below the top of the hill. The drift on the hanging-wall " vein " was run about 130 feet and a small amount of stoping was done. The " vein " was rich in mica to a point within 15 feet of the end of this drift, but at the end the mica content was low. A crosscut connects this drift with the foot-wall " vein," the drift on which was carried about 250 feet to the northwest. For 100 feet of this length the "vein " has been stoped out, to the top of the knob 50 feet above, and beyond this stretch good vein matter is held ready for stoping. At the southeast limit of the surface workings, about 200 feet from the shaft, the pegmatite contains a large quantity

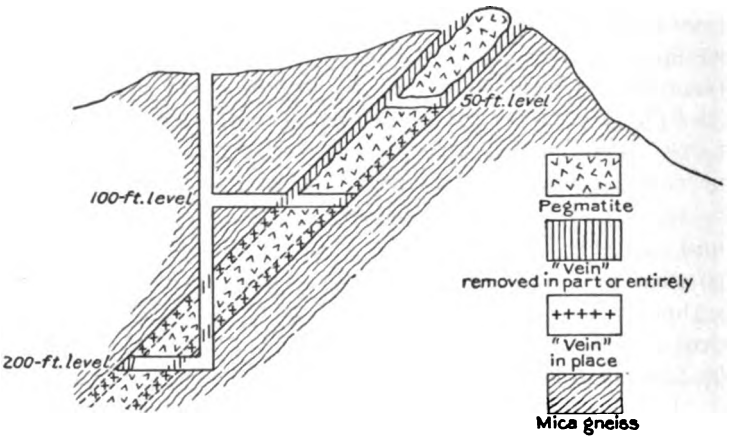

FIGURE 29.—Generalized cross section of No. 1 or New York mine, near Custer, S. Dak.

of black tourmaline in crystals ranging from 1 inch to several inches in diameter and as many feet long. The mica content of the pegmatite is very low at this point.

The shaft is located to the southwest of the pegmatite, through which it cuts between the 100-foot and 200-foot levels. Only the hanging wall has been worked on the 100-foot level. This level is connected with the shaft to the southwest by a short crosscut. Drifts have been run from the crosscut about 300 feet to the northwest and 250 feet to the southeast. The vein was stoped out to the 50-foot level for a distance of 200 feet to the northwest and work was being carried farther. The pegmatite at the end of this drift was found to be very poor in mica and to be composed of large feldspar crystals, massive quartz, rosettes of radiated feldspar columns, 8 to 12 inches in diameter, and black tourmaline. The drift was to be carried

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farther in search of richer "vein" matter. In the southeast drift much of the "vein" has been stoped out to the surface for a distance of about 240 feet from the crosscut. At this point the vein becomes poor in mica and carries abundant black tourmaline like that seen in the surface workings. Some of the tourmaline crystals measure 10 inches in diameter. They do not appear to have any definite position relative to the wall of the pegmatite. The vein was found to be rich nearly to the end of each drift and in the large stopes. The strike of the contact of the vein is nearly straight throughout the length of the drifts except at one point a few feet southeast of the crosscut. Here the mica schist wall elbows out into the pegmatite for several feet across the strike of the vein.

A room has been made southeast of the shaft on the 200-foot level for the placing of an electric pump, loading cars on the cage, etc. A crosscut of 10 feet from this room to the southwest cuts the foot wall of the pegmatite, which is about 28 feet thick. Mica is present in the foot-wall "vein" here, but it had not been developed at the time of visit. Drifts were started on the hanging-wall "vein" in each direction and when seen were each in about 20 feet. These drifts have since been carried 175 feet to the northwest and 125 feet to the southeast. At the end of the southeast drift an irregularity in the "vein" or a fault has been encountered and is being investigated by the company. The vein matter seen in the 40 feet of drift on the 200-foot level was very rich and contained considerable large-sized mica. Several blocks over a foot across and a large number of smaller ones were seen in the walls.

Mention has already been made of the richness in mica of various parts of the "vein." Data for estimating the percentage of mica in the "veins" are given by Mr. Pyne, the superintendent, whose records show an average of 600 pounds of rough mica to 10 square feet of "vein" removed. The "veins" average from 5 to 6 feet thick, say 5½ feet. If the weight of a cubic foot of pegmatite is estimated at 163 pounds, it is found that the rough mica obtained averages about 6.6 per cent of the vein matter.

No. 2 MINE.

The No. 2 mine of the Westinghouse Company, formerly known as the White Spar mine, is 1¾ miles S. 40° W. of Custer. This mine has been equipped with two 45-horsepower boilers, a bucket hoist also serving as a pump, electric lights, air drills, mine cars, and tracks. It was opened irregularly from the surface by open cuts, inclines, and drifts to a depth in places of nearly 40 feet. The workings of the present company consist of a vertical shaft 110 feet deep, 10 feet at the bottom serving as a sump, with a crosscut and drift on the "vein" at the 100-foot level and drifts and stopes on the 50-foot

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level. The shaft is in the " vein " for 50 feet from the surface down and then passes through the foot wall into the country rock. A general plan of the workings of the Westinghouse Company on the 50-foot and 100-foot levels, as seen in August, 1908, is given in figure 2. The " vein " is about 40 feet thick at its outcrop, 25 feet thick at the 50-foot level, and 18 to 20 feet thick at the 100-foot level.

The country rock is biotite gneiss, in which highly schistose beds are prominent. Some of the more schistose layers are much crumpled. The gneiss has a strike varying from N. 30° W. to N. 60° W. and a dip of about 45° SW., though the dip is variable in places. The pegmatite is roughly conformable with the inclosing biotite gneiss, though locally very irregular. On the 50-foot level it pinches out at a distance of 40 feet southeast of the shaft, and the gneiss folds around it, as indicated in figure 30. In places the contact of the pegmatite and gneiss is straight, though as a rule it is somewhat curved and rolling.

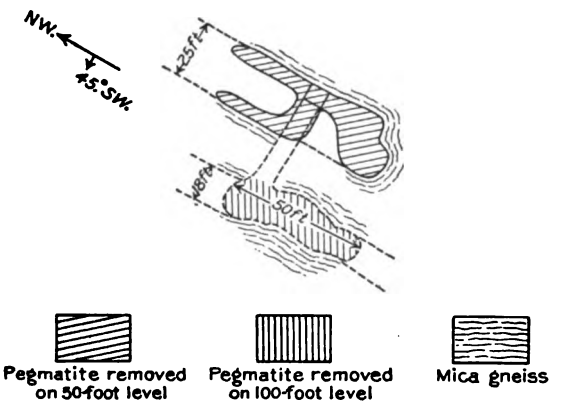

FIGURE 30.—Plan of No. 2 or White Spar mica mine, near Custer, S. Dak.

The mica is distributed through the pegmatite with varying regularity. In some places the pegmatite contains little mica for several feet in different directions; in others it is very rich for equally large areas. It was estimated that in one such portion southeast of the shaft on the 50-foot level mica composed nearly 50 per cent of the pegmatite. This mica occurred in blocks of all sizes up to a foot in diameter. The edge of one block of mica, or several blocks closely joined together, projecting from the floor of the room southeast of the shaft, was nearly 5 feet long and from 2 or 3 to 12 inches thick in different parts. The mica crystals do not appear to have any definite orientation, but lie mixed with the quartz and feldspar of the pegmatite. The feldspar is coarsely crystallized, and in one place a section of an orthoclase crystal 4 feet through was seen in the wall. Quartz occurs in large, irregular masses, several feet through, in the pegmatite. Other minerals found are black tourmaline, a few garnets, and white to pale-greenish beryl. One broken beryl crystal 6 inches in diameter and 8 inches long was seen. The mica is of good quality for many electric purposes, and some of it could be used for glazing. Part of it contains inclusions of flat-

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tened garnets between the laminæ and tourmaline grown through the crystals at different angles.

Pegmatite ledges are plentiful in the neighborhood and two other large ones outcrop about 50 to 80 feet to the southwest of the main ledge. It was intended to continue the crosscut on the 100-foot level to cut one of these.

No. 3 MINE.

The No. 3 mica mine of the Westinghouse Company is 3½ miles west of Custer and has not yet been actively developed.

No. 4 MINE.

The No. 4 mica mine of the Westinghouse Company is 5 miles N. 15° E. of Custer, in a ridge separating two branches of the headwaters of French Creek. The mine is about 300 feet higher than the valley on the northwest. The greater part of the work was done before the Westinghouse Company took hold, and that company abandoned work temporarily after a small amount of development. Openings have been made at two points—one on a small knob, the other about 200 yards S. 65° E. of it. These openings are apparently on different pegmatite bodies. The pegmatite ledge running through the knob strikes N. 15° W. and dips 60° E. The ledge at the other opening has a complex structure and its direction was not determined. Between the two openings a strong ledge of pegmatite outcrops with a strike of N. 65° W. and a dip of 40° N. This ledge extends to that on the knob, by which it seems to be cut off. Other pegmatite bodies with similar variable directions occur in the vicinity.

The pegmatite cutting through the knob is about 25 feet thick and has been traced to the south along the knob for a distance of nearly 100 yards. It is composed of large, irregular masses of feldspar and pale rose-colored quartz, with variable amounts of mica and black tourmaline and small quantities of biotite mica, apatite, and garnet. The mica seems to occur principally along the hanging wall, which has been worked by an open cut on the north end of the knob. Many mica crystals project from the pegmatite for some distance along the outcrop.

At the other opening a tunnel was run in from an open cut in a direction N. 60° W. At the entrance to this tunnel biotite gneiss was exposed in the floor and on one side. It had a strike of N. 65° W. and a dip of about 30° N. In the open cut the pegmatite dips in the opposite direction. Mica seemed to have been found plentiful and of fair size in this opening.

CROWN MINE.

The Crown mica mine, of the Chicago Mica Company, is 2½ miles northwest of Custer. It has been worked by several open cuts—the

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main one about 130 feet long and 25 feet deep and wide—a 20-foot incline from the bottom of the cut, and a 100-foot shaft with a crosscut to the "vein," a drift, and a stope. The stope reaches about halfway to the bottom of the incline. The mine has been equipped with a 40-horsepower boiler, hoisting engine, and air-drill compressor, three pumps, storage and loading house, office, etc.

The country rock is muscovite-biotite gneiss, with straight slaty cleavage in some places and a plicated structure in others, especially near the pegmatite bodies. The gneiss strikes about N. 35° W. and has a variable dip. The pegmatite is about 10 feet thick and is in part, at least, conformable with the schistosity of the gneiss. It has the form of an anticlinal fold whose axis pitches southeastward about 10° or 15° down the slope of a low ridge. At the northwest end of the open cut the crest of folded pegmatite forms a blanket over the top of a small hill and has been worked for a width of 40 feet by a shallow open cut. The northeastern limb of the fold has been followed down on a dip of about 40° by a 20-foot incline. Sufficient development work has not been done to determine the dip of the other limb of the fold to the southwest. The open cut has been made along the axis of the fold and cuts through the pegmatite.

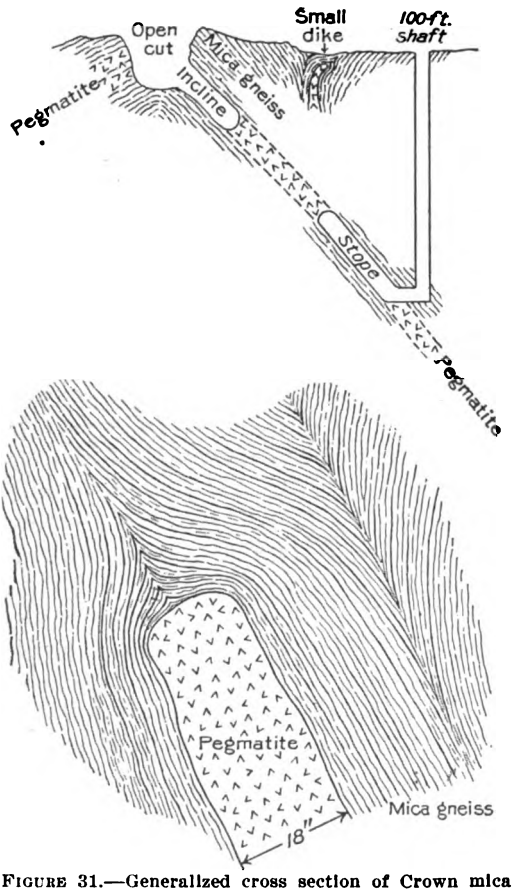

FIGURE 31.—Generalized cross section of Crown mica mine, near Custer, S. Dak., with sketch showing relation of pegmatite dike to inclosing gneiss.

While assessment work was being done, an 18-inch pegmatite dike was encountered about 50 feet northeast of the main body. This pegmatite failed to reach as far as the present surface by several feet and was discovered by accident. It is conformable with the strike of the inclosing gneiss, which it has split apart and crushed in the direction of its intrusion. The mica gneiss between this small

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dike and the main one is somewhat plicated and has been folded into a syncline. Figure 31 gives a generalized cross section of the formation and development work at this mine, also a sketch of the small dike and its relation to the inclosing gneiss. The main pegmatite body contains inclusions or horses of mica gneiss in long streaks lying parallel to the walls and ranging from a few inches to 2 or 3 feet in thickness.

In portions of the exposures of pegmatite remaining in the mine mica is plentiful, though only small sizes have been left. The small dike does not carry merchantable mica, so far as it has been opened, but is of interest as an illustration of the method of intrusion of a pegmatite dike and also of the way in which such dikes, and consequently some mica veins, pinch out abruptly.

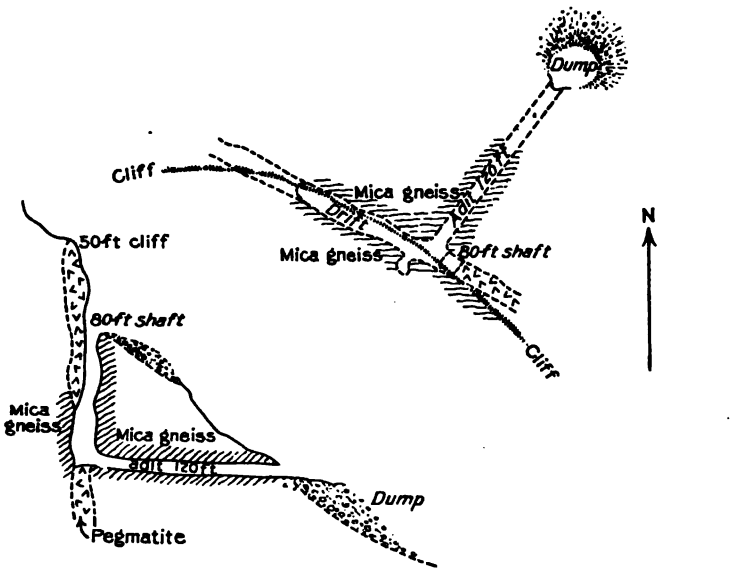

FIGURE 32.—Plan and cross section of Great Northern or Old Mike mica mine, near Custer, S. Dak.

OLD MIKE MINE.

The Old Mike mica mine, now called the Great Northern, is 3¾ miles N. 20° W. of Custer, on the north end of the ridge extending northward from Buckhorn Mountain. The pegmatite at this mine forms a cliff facing northeastward and rising about 50 feet above the steep slope at its base. Other cliffs rise back of and above this one to the southwest. The mine has been opened by a shaft 80 feet deep, a crosscut or adit 120 feet long, and a drift with stopes on the vein. (See figure 32.) A small amount of work has been done at the base of the cliff. The country rock is muscovite-biotite schist, which

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strikes nearly east and west and has a northerly dip. The pegmatite cuts across the schist with a strike of N. 65° W. and a vertical dip. It is from 10 to 15 feet thick in the drift and has irregular curving walls. The mica is irregularly distributed through the pegmatite and in some of the places, where the latter bulges out into the schist, is abundant. Here and there the pegmatite is fine grained and barren of merchantable mica. Mica is exposed in the face of the cliff, where a little work has been done. Most of the work in the cliff has been done for the columbite and cassiterite, which have been found here in varying amounts. Masses and crystals of columbite several pounds in weight have been obtained alongside of and in a quartz streak in the pegmatite cliff. Crystals of brownish to black cassiterite occur in places through the finer-grained portions of the pegmatite, and bowlders of the tin-bearing pegmatite lie on the slope of the mountain below the mine. The mica from this mine has a "rum" color and appears to be clearer than that from many of the other South Dakota mines.

FIRESTONE MINE.

The Firestone mica mine is 4¾ miles S. 20° W. of Custer. It has been opened by a crosscut through the schist and barren portion of the pegmatite, an open cut 20 feet deep, and an incline on the "vein." The incline was reported to be 75 feet deep, and has a 30-foot drift to the northeast at the 20-foot level, below which the incline is filled with water. The country rock is muscovite-biotite schist striking N. 25° E. and dipping 60° NW. The pegmatite is about 15 feet thick, and is conformable with the inclosing rock. A few thin sheets or partings of schist are included in the pegmatite and lie parallel with its walls. Near the outcrop on the southwest side of the open cut, part way down the incline, the mica streak is along the hanging wall and is about 1 foot thick. In the northeast face of the cut the mica streak is in the midst of the pegmatite and is about 4 feet thick. In the drift also the "vein" is in the body of the pegmatite, and has a thickness of several feet. Mica seems to be plentiful in portions of the "vein," and some crystals several inches in diameter were seen. The feldspar and quartz of the pegmatite occur in irregular masses 2 or 3 feet across. Some of the quartz has a pale rose color.

LOST BONANZA MINE.

The Lost Bonanza mica mine is 1¾ miles due north of Custer, on the east end of Buckhorn Mountain. The pegmatite cuts through a small knob with a strike of N. 80° W. and a dip of 40° S., and is conformable with the inclosing muscovite-biotite gneiss. The mine has been worked by an open cut with an incline and a tunnel over 200 feet long with stopes. The tunnel is about 40 feet lower than the top of the hill, and almost all of the "vein" between the two

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has been worked out. The outcrop of the pegmatite is exposed for nearly 100 yards along the strike. The pegmatite varies from 15 inches to over 8 feet in thickness. At the east end of the open cut a portion of the pegmatite is nearly barren of mica, and carries a large amount of black tourmaline crystals, some of which measure 6 and 10 inches in diameter.

CLIMAX MINE.

The Climax mica mine is 2 miles due east of Custer. It has been opened by three shafts, not over 50 feet apart, connected by drifts. One of these shafts was more than 60 feet deep. The country rock is schistose-biotite gneiss, striking northeastward and having a high dip, and the pegmatite is approximately conformable with it. As seen in the outcrop, the pegmatite is about 20 feet thick and carries mica in pockets containing crystals up to several inches in diameter. Regular streaks of mica may have been found in the workings. The mica is of good quality and has a wine-yellow color. Black tourmaline and smoky and opalescent quartz occur in the pegmatite.

About 100 yards northwest of the old workings another pegmatite body 2½ to 4 feet thick has been opened by a shaft and drifts with a small open cut. This "vein" lies conformable with the inclosing biotite schist-gneiss, which strikes N. 45° W. and has a vertical dip. The mica is scattered through the pegmatite.

ST. LOUIS MINE.

The mine of the St. Louis Mica Company is on the south side of French Creek, 4½ miles S. 65° E. of Custer. The pegmatite outcrop at this mine forms a bare floor nearly 100 feet square on the gentle slope of a hill. Several small streaks of mica gneiss with a strike of N. 70° W. and a dip of 65° SW. are included in it. Streaks of mica occur in different portions of the pegmatite and two of these have a northeasterly strike and a vertical dip. Small mica crystals are plentiful in these streaks. The development work consists of shafts and several open cuts. These openings were in such bad shape that little could be seen of the formation encountered. Good-sized blocks of mica are reported to have been found when the mine was operated.

GALESBURG MINE.

The mine of the Galesburg Mica Company is on the opposite side of French Creek from the St. Louis mine and 4½ miles S. 70° E. of Custer. It is in a sharp spur rising from the bottom land of French Creek. The spur is a hogback formed by the outcrop of a hard pegmatite ledge, which strikes about N. 70° W., dips 45° N., and is over 25 feet across. The hanging wall is biotite mica gneiss. The foot wall and full thickness of the pegmatite are not exposed. The whole has a roughly banded structure somewhat as follows: Next to the

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hanging wall is the "vein," or streak rich in mica, from 6 inches to 2 feet or more thick; then 10 to 15 feet of ordinary pegmatitic material; a massive quartz streak 6 to 10 feet thick; and more pegmatite with rosettes of feldspar (in part, at least, albite). Black tourmaline occurs through the pegmatite as usual.

PHILIP GEERING PROSPECT.

The Philip Geering prospect is 2¾ miles S. 25° W. of Custer, on the southwest side of a prominent outcrop of pegmatite, which is about 35 feet across and stands 25 feet above the level country around it. The country rock is mica gneiss and, with the inclosed pegmatite, strikes N. 25° W. and dips about 45° SW. An interesting feature at this prospect is the abundance of black tourmaline crystals in the pegmatite. These crystals range from 1 to 6 inches in diameter, and it is estimated that they compose nearly 50 per cent of the pegmatite in an area of 40 square feet exposed in the prospect. Their position is apparently nearly normal to the wall of the pegmatite. But little mica was seen in the pegmatite and it was not learned whether a good pocket had been encountered.

WYOMING LODE.

The Wyoming mica lode, owned by F. T. Peterson, is 5¾ miles S. 15° W. of Custer. Pegmatite or pegmatitic granite forms a large portion of the country rock at this prospect. Little mica schist is exposed, but what was seen occurs in streaks included in the pegmatite and has a strike west of north and a southwest dip. The mica was found in a pocket or streak at one place; the greater part of the pegmatite in the outcrop is rather fine grained and carries only small mica. The mica obtained from the prospect has a rich "rum" color. Pink orthoclase, some with graphic intergrowths of quartz, is exposed in the pit in masses several feet across. Black tourmaline and a small amount of pale rose-colored quartz are also found.

ORIGIN OF THE PEGMATITE.

The origin of pegmatite is explained in various ways. In one place the pegmatite can be proved to be a dike; in another it is a vein. In the former it represents a magma intruded into the rock formations and crystallized; in the latter it has been deposited from magmatic solutions assisted by the presence of mineralizing vapors, as boron, fluorine, etc. Between the evident dike and vein types are found all gradations. This is to be expected, in view of the general opinion that there is no sharp line to be drawn between conditions of fusion and solution in highly aqueous magmas or concentrated magmatic solutions. Thus, although no definite statement can be

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made regarding the intermediate types of pegmatite, the distinction between the end types may be more decided. To the writer's mind most of the pegmatites associated with mica in the region around Custer resemble dikes in their nature. This opinion is gained by comparing the larger deposits with the small one and its larger mother lode at the Crown mine shown in figure 31. That the small pegmatite shown in B is a dike intruded as somewhat viscous magma is evident by the way in which it has crushed the gneiss in front of it and finally stopped in its course when it became too viscous or when the pressure became insufficient to force it farther. The rounded outline of the end is a characteristic form of highly viscous bodies. That the schists were not crushed by the force of crystal growth from material in solution is shown by the absence of any pegmatitic material along the course by which the solutions would have escaped after depositing part of their load. This small dike illustrates another point. The mica gneiss at the Crown mine has been folded somewhat, as shown in the figure. The small dike has split the axis of a sharp V-shaped fold, thus following along a line of weakness. As certain bands of the schistosity are lines of weakness, the dikes have a tendency to follow them also, thus producing pegmatite bodies more or less conformable with the inclosing gneiss.

The formation of the pegmatite bodies in the Black Hills is evidently an end phase of the granite intrusions of that region; for they cut the granite masses and in some places grade into granite itself. The age of the granite intrusions around Harney Peak and Custer has not been definitely determined. Though considered Archean by Newton and Jenney, there are indications pointing to a later age.

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SURVEY PUBLICATIONS ON MISCELLANEOUS NONMETALLIC PRODUCTS, INCLUDING MICA, GRAPHITE, FLUORSPAR, ASBESTOS, AND BARITE.

The following list includes a number of papers, published by the United States Geological Survey or by members of its staff, dealing with various nonmetallic mineral products. The United States publications, except those to which a price is affixed, may be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BAIN, H. F. Fluorspar deposits of southern Illinois. In Bulletin No. 225, pp. 505–511. 1904. 35c.

BALL, S. H. Mica in the Hartville uplift, Wyoming. In Bulletin No. 315, pp. 423–425. 1907.

——— Graphite in the Haystack Hills, Laramie County, Wyo. In Bulletin No. 315, pp. 426–428. 1907.

BREWER, W. M. Occurrences of graphite in the South. In Seventeenth Ann. Rept., pt. 3, pp. 1008–1010. 1896.

BURCHARD, E. F. Barite. In Mineral Resources U. S. for 1906, pp. 1109–1113. 1907. 50c.

——— Fluorspar. In Mineral Resources U. S. for 1906, pp. 1063–1066. 1907. 50c.

——— Fluorspar and cryolite. In Mineral Resources U. S. for 1907, pt. 2, pp. 637–641. 1908.

——— Barytes and strontium. In Mineral Resources U. S. for 1907, pt. 2, pp. 685–696. 1908.

DILLER, J. S. Asbestos. In Mineral Resources U. S. for 1906, pp. 1123–1129. 1907. 50c.

——— Asbestos. In Mineral Resources U. S. for 1907, pt. 2, pp. 711–722. 1908.

EMMONS, S. F. Fluorspar deposits of southern Illinois. In Trans. Am. Inst. Min. Eng., vol. 21, pp. 31–53. 1893.

FULLER, M. L. The occurrence and uses of mica. In Stone, vol. 19, pp. 530–532. 1899.

HAYES, C. W., and PHALEN, W. C. A commercial occurrence of barite near Cartersville, Ga. In Bulletin No. 340, pp. 458–462. 1908.

——— ——— Graphite deposits near Cartersville, Ga. In Bulletin No. 340, pp. 463–465. 1908.

HOLMES, J. A. Mica deposits in the United States. In Twentieth Ann. Rept., pt. 6, pp. 691–707. 1899.

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KEITH, A. Talc deposits of North Carolina. In Bulletin No. 213, pp. 433–438. 1903. 25c.

KEMP, J. F. Notes on the occurrence of asbestos in Lamoille and Orleans counties, Vt. In Mineral Resources U. S. for 1900, pp. 862–866. 1901. 70c.

——— Graphite in the eastern Adirondacks. In Bulletin No. 225, pp. 512–514. 1904. 35c.

PHALEN, W. C. (See Hayes, C. W., and Phalen, W. C.)

PHILLIPS, W. B. Mica mining in North Carolina. In Mineral Resources U. S. for 1887, pp. 661–671. 1888. 50c.

SMITH, G. O. Graphite in Maine. In Bulletin No. 285, pp. 480–483. 1906.

——— Graphite. In Mineral Resources U. S. for 1906, pp. 1139–1143. 1907. 50c.

SMITH, W. S. T. (See Ulrich, E. O., and Smith, W. S. T.)

STERRETT, D. B. Mica deposits of western North Carolina. In Bulletin No. 315, pp. 400–422. 1907.

——— Mica. In Mineral Resources U. S. for 1907, pt. 2, pp. 741–750. 1908.

——— Meerschaum in New Mexico. In Bulletin No. 340, pp. 466–473. 1908.

STOSE, G. W. Barite in southern Pennsylvania. In Bulletin No. 225, pp. 515–517. 1904. 35c.

ULRICH, E. O., and SMITH, W. S. T. Lead, zinc, and fluorspar deposits of western Kentucky. In Bulletin No. 213, pp. 205–213. 1903. 25c.

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